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FRANKLIN SUMNER EARLE

PHYTOPATHOLOGY

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FRANKLIN SUMNER EARLE
1856—1929

C. L. SHEAR[1]

I am glad to accept the invitation to prepare a biographical sketch of our recently departed friend and colleague, as it affords an opportunity at the same time to pay a tribute to his high character, as well as to his scientific attainments as a mycologist, horticulturist, and agronomist.

Professor Earle passed away at his home in Herradura, Cuba, January 31, 1929, after an attack of bronchitis which developed into pneumonia. He was born at Dwight, Illinois, September 4, 1856. Very early in childhood he began to show much interest in plants and animals, and this was stimulated and encouraged by his mother, Melanie Tracy Earle. Being brought up on a large fruit farm, he had ample opportunity to become familiar with plant life in its varied aspects. His father, Parker Earle, was at this time one of the largest commercial fruit growers in that part of the country, and, although not a botanist, was deeply interested in plant life in its scientific as well as its cultural and commercial aspects. On account of his favorable environment, as well as inherited tendencies toward a love of Nature and a desire to become acquainted with her secrets, the boy soon developed a deep and lasting interest in plant life in general, as well as in its horticultural aspects. These two tendencies competed for control of his activities throughout his life, as will be shown by the various lines of work in which we find him engaged at different periods. At the age of sixteen he was prepared for college and entered the University of Illinois, but his services were so much in demand in connection with his father's fruit-growing operations that he spent only part of each school year at the University. After two fall and winter terms as a special student, we find him for the next four years assisting his father in his horticultural work. In 1878, he returned again to the University as a regular student in botany, studying fungi under Professor Burrill. He withdrew in March, 1879, to return to fruit growing.

His deep interest in botany, especially the fungi, which had been stimulated by his work with Professor Burrill, brought him back to the Univer-

[1] I wish to express my gratitude to Mrs. Earle, Mrs. Wm. T. Horne, sister of Prof. Earle, and to Mr. A. B. Seymour, for information not otherwise obtainable, and to Mrs. Earle for the accompanying portrait.

sity again in 1882 as a volunteer assistant, in order to pursue his favorite study and to help Professor Burrill in working up the Erysiphaceae of Illinois. This resulted in his first mycological publication, "Notes on North American Forms of Podosphaera," 1884. Although there is no exact record at present available, it is highly probable that young Earle assisted Professor Burrill in his epoch-making studies on the bacterial cause of pear blight, which were then being carried on, as his father's pear orchards must have furnished ample opportunity for observation and experiments with this disease.

Leaving the University in 1883, he returned home again to assist his father in his fruit-growing and shipping operations, utilizing his spare moments in collecting and studying fungi, especially the powdery mildews. In 1887, the result of this work, which was a monograph of the Erysiphaceae of the state, was published under the joint authorship of Burrill and Earle. He had an opportunity during this period to accept a good position at the Kentucky Agricultural Experiment Station but declined, believing that his duty to his father and their fruit interests, then being developed in southern Mississippi, demanded his first consideration.

In 1894 and 1895, he became connected with the Mississippi Agricultural Experiment Station, and in 1895–96 he acted as Assistant Pathologist in Charge of the Mycological Herbarium of the United States Department of Agriculture. This position, again, gave him an opportunity to devote his time entirely to fungi, but in 1896 his horticultural interests and perhaps financial considerations also led him to accept the position of Horticulturist at the Alabama Agricultural Experiment Station. A little later he was made Professor of Biology at the Alabama Polytechnic Institute from which, in 1902, he received the degree of M.S. The same year he accepted a call to the New York Botanical Garden to become Assistant Curator in Charge of Mycological Collections. Here he had an opportunity to do some of his best work in systematic mycology, giving special attention to the Agaries. This was interrupted, however, in 1904, by his appointment as Director of the Estacion Central Agronomica of Cuba. He brought to his assistance in this position a group of plant and animal investigators who inaugurated research of great importance to Cuban agriculture. Owing to political changes he resigned from his position in 1906 and purchased a farm at Herradura, Cuba, where he took up fruit and truck growing, which, in spite of his numerous other activities, he continued to carry on and enjoy until the end of his life.

From 1908 to 1911 he was Consulting Agriculturist of the Cuban-American Sugar Company and, during 1911–14, President of the Cuba Fruit Exchange. In 1918, he was sent by the United States Department of

Agriculture to Porto Rico to make an investigation of the mosaic disease of sugar cane, at that time threatening the destruction of the industry. In this connection his discovery of a variety of cane practically immune from the disease and his introduction of this variety into Porto Rico were of the greatest service to the sugar planters.

In 1922–23, he was Consulting Agriculturist to the Central Aguirre Sugar Company of Porto Rico. He next returned to Cuba and became Advisor for the General Sugar Company. In 1925, he accepted a position with the Tropical Plant Research Foundation and took charge of the study of sugar-cane varieties, which was continued until his death.

The results of his twenty-years observation and experience with sugar cane were embodied in a book entitled "Sugar Can and Its Culture," which is recognized as an authoritative work on the subject. Although engaged for the greater part of his life in commercial and economic phases of agriculture and horticulture, he always retained a very deep interest in mycological and pathological work and never lost an opportunity to increase his knowledge of the subject. He at one time prepared manuscript for a work on plant pathology which he had hoped to complete and publish, but, unfortunately, this, as well as his library, was destroyed in a fire which consumed his home in Herradura.

During his sugar-cane investigations in Cuba and Porto Rico he frequently found time to collect fungi, many of which were sent to the writer and have contributed to our knowledge of the occurrence and distribution of various species found on these islands.

He was a member of the American Association for the Advancement of Science, the Torrey Botanical Club, The American Phytopathological Society, the Botanical Society of America (President, 1906), and for many years Associate Editor of Mycologia. A genus of Rusts, Earlea, has been named in his honor and several species of fungi bear his name.

The character and extent of Professor Earle's scientific work and studies are indicated by the extensive bibliography here appended. A mere catalogue of this kind, however, throws little light upon his personal characteristics. He was of optimistic temperament and a genial companion. One of my pleasantest memories is of a visit to his home in Herradura and our discussions of various mycological, pathological, and miscellaneous subjects. His sterling character, quiet and retiring manner, and friendly disposition caused him to be greatly respected by his business associates and acquaintances and beloved by his more intimate colleagues and friends.

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PHYSIOLOGIC SPECIALIZATION AND MUTATION IN PHLYCTAENA LINICOLA SPEG.[1]

H. A. RODENHISER[2]

INTRODUCTION

The pasmo disease of flax, caused by *Phlyctaena linicola* Speg., is known to have been present in the Upper Mississippi Valley a number of years. In 1928 the disease was epidemic in many fields in Minnesota, and losses as high as 20 per cent were reported. In the flax-rust nurseries at University Farm, St. Paul, Minn., and at the Coon Creek Substation, a large number of wilt- and rust-resistant selections were killed by pasmo.

Cultures were obtained from diseased plants grown in different localities in Minnesota and the cultural characters studied. The cultural characteristics of some isolations were similar to those described by Brentzel (3) for *P. linicola* but others were entirely different. Furthermore, variant sectors appeared in some colonies of monosporous origin. These facts seemed to indicate the existence of physiologic forms of the pasmo pathogene and the origin of new forms by mutation.

A study, therefore, was made of different physiologic forms in order to determine their cultural characteristics, their stability, and possible origin, as well as their pathogenicity.

MATERIALS AND METHODS

During 1928 collections of diseased flax were made in several localities in Minnesota. Diseased portions of the flax stems in which pycnidia had developed were placed in a mercuric bichloride solution, 1:1000, for three minutes and then washed in sterile distilled water. Pieces were then transferred to potato-dextrose agar, and in about five days pure cultures of *P. linicola* were obtained. From these cultures single conidia were isolated by the method described by Hanna (10) and subcultures of the colonies that developed were used in all the tests. For identification of physiologic forms the cultures were first incubated for 10 days in test tubes on equal quantities of 2 per cent potato-dextrose agar. Small, approximately equal portions of each culture were then transferred for comparative tests to equal quantities

[1] Cooperative investigations between the Agricultural Experiment Station of the University of Minnesota, and the Office of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture. Published with the approval of the Director as Paper No. 939 of the Journal Series of the Minnesota Agricultural Experiment Station.

[2] The writer wishes to express his appreciation to Dr. E. C. Stakman for help and criticism in preparing this paper.

of several different media in petri dishes or flasks of uniform size. The following characters were used in differentiating the forms on culture media: Color, topography, character of surface, consistency, and type of margin. The colors were classified according to Ridgway's "Color Standards and Color Nomenclature" (13).

Each physiologic form was designated by the locality whence it was obtained, together with an accession letter. The first form isolated in Minnesota, for example, was designated Minn. A, the second Minn. B, etc. Physiologic forms isolated from sectors are designated according to the colony in which they appeared, together, with an accession number. Thus, the first form obtained from a sector of Minn. A is Minn. A1; the second sector in Minn. A is designated as Minn. A2. Sectors occurring in Minn. A2 would be referred to as Minn. A2–1, Minn. A2–2, etc.

CULTURAL STUDIES

Several investigators (4, 5, 6, 7, 8, 12, 15) have found cultural and physicochemical differences between lines within species of various fungi. In colonies of some of these lines, sectors appeared which differed from their parent colonies in color, type of growth, and certain other characters. Christensen (6) found this to be true in monosporous cultures of *Helminthosporium sativum* P., K., and B., as did Hanna (11) in monosporous cultures of *Ustilago zeae* (Beck.) Unger.

Up to the present time eleven distinct physiologic forms of *P. linicola* have been obtained either from original isolations from diseased stems or as

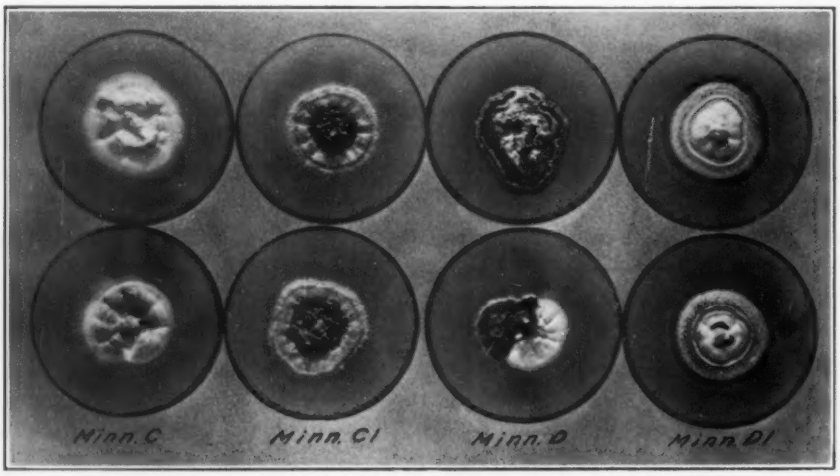

FIG. 1. Four physiologic forms of *Phlyctaena linicola* on potato-dextrose agar for 30 days. Note the fan-shape mutant developed in Minn. D.

TABLE 1.—*Cultural characteristics of physiologic forms of Phlyctaena linicola on potato-dextrose agar 30 days after inoculation*

Source of collection	Form	Color	Topography	Surface	Consistency	Margin	Conidial production
St. Paul, Minnesota	Minn. C	White to pale gull gray; center deep gull gray	Slightly umbilicate; few radial depressions	Velvety	Mycelioid	Slightly undulate	Slight
Sector from Minn. C	Minn. C1	White to pale olive-buff; center olive brown	Umbonate; center coral-like	Center waxy; ray powdery	Center leathery; ray mycelioid	Entire	Moderate
Crookston, Minnesota	Minn. D	Dusky green to glaucous-green interspersed with patches of gull gray	Raised to convex	Felty, interspersed with few very small wet blister-like areas	Mycelioid and bacterioid	Slightly lobate	Abundant
Sector from Minn. D	Minn. D1	Center white surrounded by band of neutral gray; remainder white to pale gull gray	Umbonate	Velvety	Mycelioid	Entire	Slight

mutants occurring in the form of sectors in these parental cultures. The data on cultural characteristics of four of these forms are summarized in table 1 and a photograph of the colonies is shown in figure 1. Marked differences in the color of the cultures were observed, not only between those of physiologic forms isolated directly from diseased flax but also between parent cultures and mutants. For example, under the conditions of the experiment, Minn. C was white to pale gull gray, with a center of deep gull gray. A mutant from this culture, Minn. C1, was white to pale olive-buff with a center of olive brown. The topography of the colonies varied from flat to umbilicate, the surface from dull to velvety and waxy, the consistency mycelioid to leathery, and the margin entire to slightly lobate. When grown under the same environmental conditions the cultural characteristics of any particular form were very constant (Fig. 1). On the other hand, the same forms grown at different temperatures and on different media were quite different in their cultural characteristics. Similar facts have been observed by Christensen (6) for *Helminthosporium sativum*, by Christensen and Stakman (8) for *Ustilago zeae*, and by Rodenhiser (14) for some of the cereal smuts. There is a difference also in the degree to which certain of the forms produce conidia. For example, Minn. D produced conidia abundantly, while Minn. C was almost entirely mycelioid and relatively few conidia were formed. Minn. D1, isolated from a sector in Minn. D, likewise was mycelioid and produced very few conidia. These cultures were transferred every three weeks, for one year, and this difference in conidial production remained constant.

INFLUENCE OF TEMPERATURE ON THE AMOUNT OF RADIAL GROWTH OF COLONIES

Tests were made to determine whether physiologic forms of *P. linicola* could be distinguished by differences in reaction to temperature. To each of a triplicate series of Erlenmeyer flasks of 250 cc. capacity were added 35 cc. of the same preparation of 2 per cent potato-dextrose agar. The flasks were inoculated with small, approximately equal portions of each culture and incubated at room temperature for 24 hours. All of the forms were then incubated at each of the following temperatures: 7°, 12°, 17°, 22°, 27°, and 32° C. The diameter of each colony was measured at the end of 30 days. The results of the experiment with six physiologic forms are summarized in table 2 and the data are graphically represented in figure 2. Brentzel (3) found the cardinal temperatures of *P. linicola* to be about 5°, 21°, and 32° C. From the data presented in table 2 it may be seen that the results obtained by the writer are corroborative. It seems clear, also, from these data, that physiologic forms of the organism react differently at certain temperatures. At the end of 30 days incubation at 17° C. the average diameter of colonies of Minn. C was 40.7 mm., while those of

TABLE 2.—*The influence of temperature on the growth of six physiologic forms of Phlyctaena linicola on potato-dextrose agar for 30 days*

Form	Temperature in degrees C. and diameter of colonies in mm.																	
	7				12				17				22				27				32			
	Series				Series				Series				Series				Series				Series			
	1	2	3	Av.	1	2	3	Av.	1	2	3	Av.	1	2	3	Av.	1	2	3	Av.	1	2	3	Av.
Minn. A	9	7	5	7.0	12	18	17	15.7	26	31	26	27.7	35	—	29	32.0	25	25	28	26.0	0	0	0	0
Minn. B	10	12	11	11.0	20	20	—	20.0	22	18	—	20.0	27	25	—	26.0	25	26	17	22.7	0	0	0	0
Minn. C	10	11	9	10.0	20	22	19	20.3	40	40	42	40.7	44	44	45	44.3	22	26	26	24.7	tr	tr	tr	tr
Minn. C1	10	10	15	11.7	24	19	21	21.3	28	29	—	28.5	47	45	48	46.7	21	24	23	22.7	0	0	0	0
Minn. D	11	10	9	10.0	20	15	15	16.7	18	20	23	20.3	32	25	32	29.7	18	23	21	20.7	tr	tr	tr	tr
Minn. D1	11	10	10	10.3	18	16	17	17.0	24	25	26	25.0	47	44	45	45.3	30	31	30	30.3	tr+	tr+	tr+	tr+

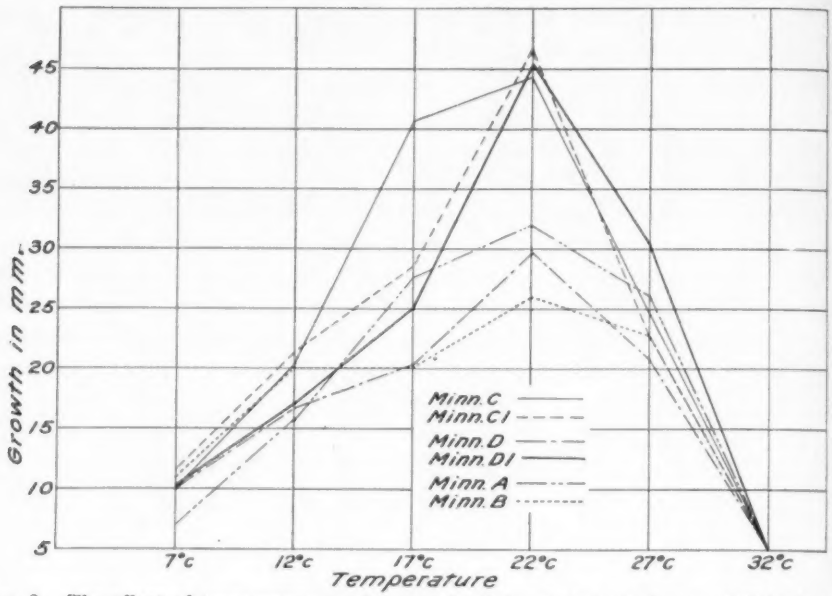

FIG. 2. The effect of temperature on the growth of six physiologic forms of *Phlyctaena linicola* on potato-dextrose agar for 30 days.

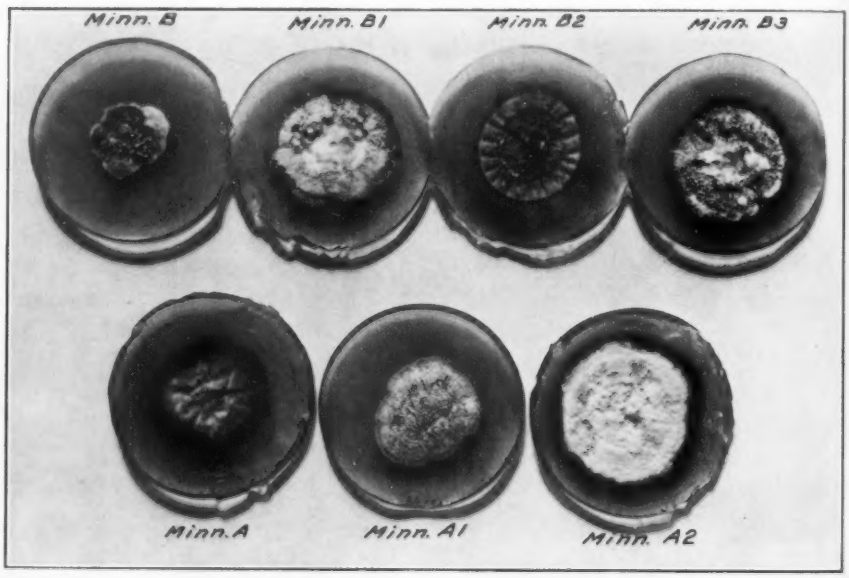

FIG. 3. Cultures of physiologic forms of *Phlyctaena linicola* showing differences in characteristics between parents and mutants. Minn. B and three mutants. Minn. A and two mutants.

Minn. B and Minn. D were 20.0 mm. and 20.3 mm., respectively. When incubated at certain temperatures there were differences in the amount of radial growth of parent colonies and mutants. When incubated at 17° C. the diameters of colonies of Minn. C averaged 40.7 mm., while those of Minn. C1 averaged 28.5 mm. At 22° C. there was a difference of only 2.4 mm. in their average diameter, the colonies of Minn. C1 being slightly larger than those of the parent, Minn. C. In general, cultures of mutants grew more rapidly than parental cultures, but not always. At 12° C. colonies of Minn. D and the mutant Minn. D1 reacted approximately the same, but at 17°, 20°, and 27° C. the average diameters of the parental colonies were much smaller than those of the mutant, the differences being 4.7 mm., 15.6 mm., and 9.6 mm., respectively.

VARIABILITY AND MUTATION

The range of variability in cultural characters of physiologic forms is very large (Figs. 1, 3). By changing the environment under which the cultures are grown decided temporary modifications can be induced. The genotypic constitution does not seem to be changed, however, as the modifications assume the original characters when again grown under fairly normal conditions. Furthermore, under the same environmental conditions the characters of any given line are remarkably constant. Similar facts have been observed for *Helminthosporium sativum* (7), for *Ustilago zeae* (8), for some of the cereal smuts (14), and for *Sphacelotheca sorghi* (9). There seems to be every reason to suppose from the observations made by the writer that the physiologic forms of *P. linicola* differ from each other genotypically and that these characters, although subject to considerable fluctuation, are constant under uniform conditions. When new physiologic forms appear they seem to arise in the form of definite sectors in colonies (see Fig. 4).

The sectors in colonies of *P. linicola* were usually wedge- or fan-shape, although in two instances new forms were isolated from irregularly outlined patches that appeared near the center of the parental colony. When transfers were made from these variants, repeated sectoring took place in the resulting colonies to the extent that there were sectors within sectors. The cultures obtained from these sectors retained their characteristics for a considerable period of time and when there were reversions to the parental type they came about as a result of sectoring.

The question arises as to whether the sectors described represent mutations. Several investigators (2, 5, 6, 7, 8, 15) have described mutations in fungus colonies growing on culture media. It is beyond the province of this paper to discuss in detail the arguments for and against the designation of sectors in fungus colonies as mutants. If one accepts Baur's (1, p.

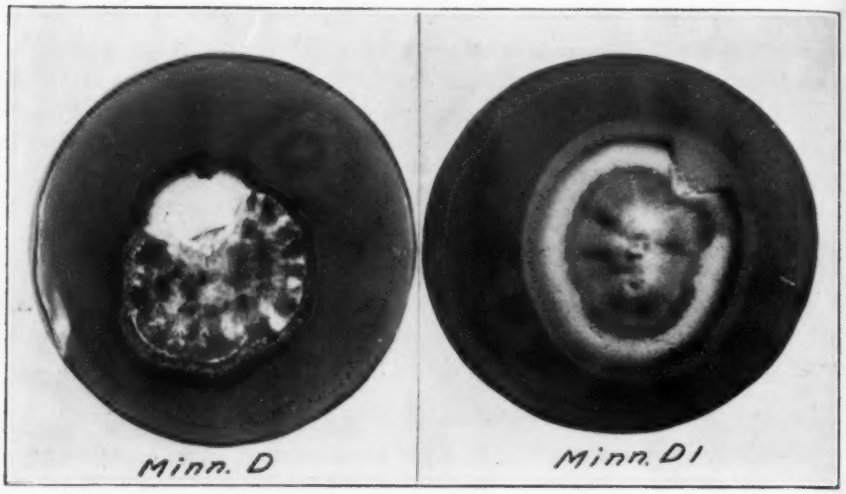

FIG. 4. Mutants arising as distinct sectors in colonies of *Phlyctaena linicola*. Minn D1 was isolated from the sector in Minn D. Note that Minn D1 is again sectoring.

436) definition of mutation, that is, heritable differences between parents and their offspring, including those that have originated asexually, which do not arise through hybridization but which have other causes, it would seem justifiable to designate as mutants the new lines of *P. linicola* which have been isolated as sectors in colonies of monosporous lines. The differences in cultural characteristics between the parents and the so-called mutants certainly have persisted through a number of asexually propagated generations and no anastomosing of hyphae or fusions between conidia ever have been observed. It seems unlikely, therefore, that the sectors are the result of chance assortment of nuclei. This seems particularly true because the individual cells of the conidia are uninucleate. Whether one designates as mutation or saltation the process by which new physiologic forms originate in the form of sectors is probably unimportant. It does seem significant, however, that new physiologic forms actually are originating in this manner.

PATHOGENICITY

An attempt was made to find out whether these forms differed in pathogenicity also. In the greenhouse the following flax varieties and selections were inoculated with four culturally distinct forms: Winona C. I. 179, Chippewa C. I. 178, Ottawa C. I. 24, Argentine (C. I. not known), and an Argentine-by-Saginaw cross. Water suspensions of cultures of Minn. C, Minn. C1, Minn. D, and Minn. D1 were used and approximately equal amounts of the inoculum sprayed on the flax plants with a Daisy hand

sprayer. Four pots of each variety or selection, containing six plants each, were inoculated with the individual physiologic forms, respectively, about the time of boll formation. After an incubation period of nine days the characteristic lesions appeared on the leaves and two weeks later they were well developed on the stems. In no case did there appear to be an appreciable difference in the pathogenicity of the different physiologic forms. Several leaves on all of the plants were infected and from three to five lesions developed on each stem. The symptoms on the Argentine plants developed two days before those on the other varieties or selections.

Nine varieties and selections of flax were inoculated in the field with two physiologic forms of *P. linicola*, as indicated in table 3. Approxi-

TABLE 3.—*Summary of data on tests for pathogenicity of two physiologic forms of Phlyctaena linicola at University Farm, St. Paul, Minn., in 1929*

Variety or selection of flax	C. I. No.	Degree of infection from					
		Minn. D		Minn. D1		Noninoculated	
		Series		Series		Series	
		A	B	A	B	A	B
Red Wing	480	H[a]	H	L–	L–	T	O
Winona	179	H–	H	T	T+	O	T
Slope	274	M	M+	L+	L	O	T
Buda	336	M	M	T	T+	O	O
Bison	389	M	M	L–	L–	T	T
Linota	433	M+	M	T	T+	T	T
N. D. R. 114	268	M+	M+	T	T+	O	T
Reo (L. 79)	280	M+	H	L	L–	L	T+
Argentine (Selection)	—	H	H	T+	L–	T	T+

[a] H = heavy; M = moderate; L = light; T = trace.

mately 125 seeds of each variety or selection were planted in duplicate seven foot rows, replicated twice. After the bolls had formed, the plants in one series were sprayed five times at intervals of four days with water suspensions of cultures of Minn. D and in a duplicate series with Minn. D1. From the data presented in table 3 it would seem that Minn. D is more virulent than Minn. D1. In the greenhouse tests, however, no difference was found in the pathogenicity of these two physiologic forms. An explanation of the differences in degrees of infection obtained in greenhouse and field trials may be as follows: Minn. D in culture produces conidia abundantly, while Minn. D1 produces few conidia and is almost entirely mycelioid. In the greenhouse, a short time after the lesions appeared on the leaves and stems the plants dried up and, consequently, lesions resulting

from secondary infections did not develop. In the field, conditions for secondary infection were optimum and plants inoculated with a physiologic form that produces conidia abundantly would be apt to be more heavily infected than those plants inoculated with a form such as Minn. D1 which produces relatively few conidia. From the data presented in table 3 it will be noted also that certain varieties and selections in the check series became infected. Unfortunately, the seed for this series was sown near some very susceptible Argentine selections wherein pasmo developed as a result of natural inoculation. When preliminary notes were taken the disease had not spread to the check series but, when the final readings were made, lesions had developed on the leaves. It is presumed that the inoculum came from the adjacent plots of Argentine flax.

VARIETAL RESISTANCE

In 1928, in the flax-rust nurseries at University Farm, St. Paul, Minn., and at the Coon Creek substation, and, again, in 1929, at University Farm, many selections of flax, highly resistant to wilt and rust, were killed by pasmo. In the nurseries several commercial flax varieties were grown and, in addition, about six hundred selections of the following crosses: Argentine by Saginaw, Argentine by Winona, Saginaw by Ottawa, Winona by Ottawa, Winona by Bombay, Winona by Montevideo, Blue Blossom Dutch by Bombay, and Saginaw by Bombay. In the commercial varieties the degrees of resistance varied; the Argentine flaxes were completely susceptible, while Red Wing C. I. 480, Winona C. I. 179, Chippewa C. I. 178, Linota C. I. 433, and North Dakota C. I. 268 were moderately so. Buda C. I. 336 and Bison C. I. 389 were resistant. In the selections from the various crosses there were all gradations from a high degree of resistance to complete susceptibility. Resistance, then, is not correlated with any particular agronomic type, and it should be possible to breed varieties of flax possessing desirable agronomic characteristics and high resistance to pasmo.

DISCUSSION AND CONCLUSIONS

There are at least several physiologic forms of *P. linicola* that differ culturally, in temperature relations, in conidial production, and to a certain extent in pathogenicity. Not only are there several forms now extant but, no doubt, new ones are continually being produced; at least, they arise on culture media by the process of mutation, if the sectoring in colonies can properly be designated as mutation. That these so-called mutants are not mere temporary variants is indicated by the fact that their characters remain remarkably constant under uniform conditions except as changes again may occur as a result of sectoring. It seems quite likely that the differential effect of temperature on different physiologic forms may deter-

mine, to a considerable extent, which forms are likely to predominate in certain regions or in certain seasons. The further fact that some forms produce conidia far more abundantly than others probably enables the former to do greater damage because of their ability to cause secondary infections. There apparently are all gradations in susceptibility among varieties of flax ranging from complete susceptibility to high degree of resistance. Resistance does not seem correlated with any particular agronomic type, and it should therefore be possible to breed varieties that combine desirable agronomic characters with resistance to pasmo.

SUMMARY

1. *Phlyctaena linicola* comprises distinct physiologic forms that can be distinguished in culture by the following characters: Color, topography, surface, consistency, type of margin, and the degree to which conidia are produced.

2. The differences between physiologic forms in culture sometimes are very great. When grown under the same environmental conditions, the cultural characteristics are constant. Temporary modifications may be induced but the genotypic constitution is not changed, for the variants assume their original characteristics when the forms are again grown under normal conditions.

3. The temperature relations of different physiologic forms differ. This is indicated by the fact that the amount of radial growth differs greatly at different temperatures.

4. Wedge-shape sectors appear commonly in colonies of the organism on culture media. The cultures isolated from these sectors retain their distinctive characters for long periods of time and the writer considers the preponderance of evidence to indicate that they are true mutants.

5. The mutants are as stable as the forms originally isolated from the diseased plants.

6. Physiologic forms of the pasmo organism differ in the degree to which they produce conidia. Under experimental conditions, secondary infections were most numerous when forms were present that produced conidia abundantly. The number of secondary infections was far lower when the form present produced relatively few conidia.

7. Flax varieties and selections varied considerably in their resistance to pasmo. All gradations of resistance and susceptibility were found. None of the lines were found to be immune.

8. There seems to be no correlation between agronomic type in flax and resistance to pasmo. It should be possible, therefore, to breed resistant varieties of the desired agronomic type.

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PURIFICATION AND CERTAIN PROPERTIES OF THE VIRUS OF TYPICAL TOMATO MOSAIC[1]

P. H. Brewer, H. R. Kraybill, R. W. Samson, and M. W. Gardner

Various methods (4) have been employed in attempting to free the tomato-mosaic virus as completely as possible from the different constituents of the plant juice and the best success has been obtained by supercentrifuging the juice expressed from large quantities of minced mosaic-plant tissue, discarding the liquid, which contains most of the soluble constituents of the cell sap, and releasing the virus from the solid residue in distilled water, supercentrifuging a second time, and clearing and decolorizing the liquid thus obtained by the use of aluminum-gel acid in reaction (5).

Clear and colorless virus suspensions thus prepared have been found to lose their virulence after passage through atmometer cylinders, Pasteur-Chamberland B filters, and collodion filters and after heating to 84° to 88° C., and, in general, to remain active for long periods under conditions of refrigerator storage. The virus is inactivated when the suspension is made more alkaline than pH 8.5 and reactivated when the acidity is restored. Evidence was obtained that the virus, under the influence of the electric current, passed to the positive pole.

MOSAIC VIRUS OBTAINED FROM RESIDUE IN SUPERCENTRIFUGE AND PURIFIED WITH ALUMINUM GEL

To obtain the mosaic virus a number of tomato plants affected with the typical mosaic [Type A of Fernow (7), Tobacco Virus 1 of Johnson (9)] are ground in a food chopper and the juice expressed through heavy muslin in a Cossette porcelain press. This juice is diluted with an equal volume of water and passed through a Sharples laboratory supercentrifuge three times at the rate of 12, 6, and 3 liters per hour, respectively, and at about 35,000 revolutions per minute. The liquid, which contains most of the soluble constituents of the plant juice, and which, according to McKinney's supercentrifuge tests with tobacco (13, p. 34), should contain relatively little of the virus, was discarded. The dark green, gummy residue, which in McKinney's tests (13, p. 34) contained most of the virus, is scraped from the bowl of the centrifuge, resuspended in distilled water by

[1] Contribution from the State Chemist and Botany Departments, Purdue University Agricultural Experiment Station, and the Agronomy Department, School of Agriculture, La Fayette, Indiana.

stirring with a Bouyoucos deflocculator, and again passed through the supercentrifuge. The residue is discarded. To the centrifuged liquid, which is somewhat yellowish and cloudy, is added aluminum gel prepared so as to have a slightly acid reaction, a precaution which prevents it from inactivating the virus, as in Allard's tests (2). By adsorption the aluminum gel removes the suspended solids and the yellowish color and, when the mixture is filtered, the filtrate is a clear and colorless suspension of the virus which upon inoculation proves as infectious, apparently, as the juice originally expressed from the plants.

In the course of this work many virus suspensions have been thus prepared and purified and nearly all have given 100 per cent mosaic infection when inoculated into sets of 10 or 15 young tomato plants grown in an insect-free greenhouse.

Inoculation is performed by means of small glass tubes drawn out to a narrow point. Rather large numbers of these small pipettes, washed and sterilized, are kept on hand and a fresh pipette is used for each plant inoculated. By inserting the point of the pipette into the virus suspension in a test tube, a small amount is drawn up into the pipette by capillarity. In performing the inoculation, two or three leaves of each plant are scratched about three times with the point of the pipette from which a small amount of the virus suspension escapes into the wound as it is made. While the leaf is being inoculated it is supported on a small piece of paper toweling to prevent contact with the hand. By using a fresh pipette and paper for each plant there is no danger of accidental transfer of a virus from one plant to another. In the course of this work there has been a minimum of accidental infection. Series of control plants not handled at all, or inoculated with tap water, have remained free from infection.

With clear and colorless virus suspensions freed from all of the coarser solids and most of the soluble constituents of the plant juice and yet remaining actively infectious, it is believed that the various properties of the virus may be more accurately determined.

MOSAIC VIRUS FILTERED OUT BY ATMOMETER CYLINDER, PASTEUR-CHAMBERLAND B, AND COLLODION FILTERS

Virus suspensions purified by the method just outlined were found to be infectious after passage through a Pasteur-Chamberland F filter and Schleicher and Shüll 1½ per cent collodion filters, but not after passage through a Pasteur-Chamberland B filter, a cylindrical porous cup atmometer, Schleicher and Shüll 3, 4½, 6, and 7½ per cent collodion filters, and at 20 inches pressure and pH 4.80 through 2, 3, and 5 per cent collodion filters made with equal amounts of alcohol and ether as a solvent by pouring the

solution onto a mercury surface and exposing to the air 15 to 20 minutes before adding water. The results of the filtration tests on preparations of proved infectiousness are summarized in table 1.

After a filtration was completed the top of each of the 2, 3, and 5 per cent collodion filters was washed with distilled water and with this wash water from each filter a set of ten plants was inoculated and all of the plants in each set developed mosaic. This showed that the virus, in part at least, was retained in an easily removable condition on the filter.

TABLE 1.—*Filtration tests with purified virus of tomato mosaic*

Filter used	Plants inoculated	
	Total number	Number mosaic
Pasteur-Chamberland B	30	0
" " F	85	64
Atmometer cylinder	20	0
Schleicher and Shüll 1½%	40	9
" " 3 %	30	0
" " 4½%	40	0
" " 6 %	30	0
" " 7½%	30	0
Collodion 2 %	10	0
" 3 %	40	0
" 5 %	20	0

The failure of the virus to pass through collodion filters is in accordance with the results obtained by Kraybill and Eckerson (11) with Schleicher and Shüll and laboratory-prepared filters and, for the virus as it occurs in tobacco, by Duggar and Karrer (6), and by Mulvania (14) with filters made up with a similar proportion of alcohol in the solvent. Klebahn (10, p. 84), however, found that the virus from tobacco passed through a 2 per cent collodion filter. In his very early investigation of this virus as it occurs in tobacco, Iwanowski (8) found that it passed through a Chamberland filter. The failure of the virus to pass through the atmometer is in accordance with the results obtained by Allard (2) and Duggar and Karrer (6) with the same virus in tobacco.

The content of solids in two active filtrates from Pasteur-Chamberland F filters was found to be 0.00147 gram and 0.0018 gram per cubic centimeter or about 0.15 per cent. Examination of the original virus suspension with an ultramicroscope showed numerous particles which became progressively less abundant in the filtrates from the collodion filters as the percentage of collodion was increased. No particles whatever were visible in the filtrates from the filters containing the two highest percentages of collodion (6 per cent and 7½ per cent).

MOSAIC VIRUS ACTIVE AFTER LONG PERIODS OF REFRIGERATOR STORAGE

The virus of typical tomato mosaic in extracted plant juice is known to be exceptionally long-lived (1, 9). Storage tests at ordinary refrigerator temperatures (36°–40° F.), the results of which are presented in table 2, have shown that, in general, the purified virus suspensions were still active after 6 to 20 months. No preservative was added. Four of the nine preparations tested (Nos. 2, 4, 5, and 6) apparently weakened with age, one (No. 6) apparently having lost its virulence in 564 days.

TABLE 2.—*Effect of refrigerator storage on virulence of purified tomato-mosaic-virus suspensions*

Virus suspension	Age	Plants inoculated	
		Total number	Number mosaic
1	Fresh	15	15
	110 days	15	10
	249 "	10	9
2	Fresh	15	15
	96 days	15	8
	234 "	10	5
3	Fresh	15	15
	86 days	15	8
	225 "	10	9
	606 "	10	10
4	Fresh	15	15
	74 days	15	10
	213 "	10	6
5	Fresh	15	15
	47 days	15	7
	187 "	10	7
	567 "	10	3
6	Fresh	15	15
	44 days	15	8
	184 "	10	8
	564 "	10	0
7	Fresh	15	15
	613 days	10	10
8	Fresh	10	9
	275 days	10	10
9	Fresh	10	10
	273 days	10	10

MOSAIC VIRUS INACTIVATED AT ABOUT 88° C.

Ten-minute exposures of the purified virus suspension in test tubes to temperatures of 70° to 90° C. indicated that the virus was inactivated at

about 88° C., as has been previously found by Allard (2), Johnson (9), and McKinney (12). For example, in one series of tests in which 15 plants were inoculated from each test tube of the heated virus suspension, the tube heated at 80° C. yielded 14 mosaic plants, at 82°, 12 mosaic plants, at 84°, 6 mosaic plants, at 86°, 2 mosaic plants, at 88°, no infection, and at 90°, no infection.

Longer exposures at the lower temperatures tended to destroy the virus. For example, out of 30 plants inoculated with virus suspensions heated 25 minutes at 70° C., 23 developed mosaic; out of 40 plants inoculated from suspensions heated 25 minutes at 74° C., 28 developed mosaic; out of 60 plants inoculated from suspensions heated 25 minutes at 78° C., only 18 developed mosaic; out of 60 plants inoculated from suspensions heated 25 minutes at 82° C., only 6 developed mosaic; and none of the 20 plants inoculated from suspensions heated 25 minutes at 84° C. developed mosaic.

TABLE 3.—*Inactivation of mosaic virus by increasing alkalinity*

H-ion concentration		Plants inoculated	
Original pH	Final pH	Total number	Number mosaic
5.25	5.25	10	9
	6.01	10	8
	7.03	10	7
	7.53	10	6
	8.12	10	6
	8.50	10	6
	8.75	10	0
5.33	5.33	10	10
	6.69	10	6
	7.61	10	4
	8.04	10	0
	8.40	10	0
6.43	6.43	15	15
	7.14	15	15
	7.44	15	15
	7.53	15	14
	7.77	15	0
	7.87	15	0
	8.12	15	0
7.11	7.11	15	15
	7.28	15	14
	7.56	15	15
	7.73	15	4
	8.04	15	2
	8.29	15	0

MOSAIC VIRUS INACTIVATED WHEN SUSPENSION MADE ALKALINE AND REACTIVATED WHEN ACIDITY RESTORED

The hydrogen-ion concentration of the purified virus suspensions as determined with the quinhydrone electrode usually fell within the limits of pH 5.0 to pH 6.5. When the hydrogen-ion concentration of the virus suspension was changed by adding dilute HCl or NaOH it was found that the virus was inactivated when the suspensions were made more alkaline than pH 7.5 to pH 8.5, as shown in table 4, and was activated again when the acidity was restored (Table 5). A slight precipitate was produced at about the same point at which inactivation occurred. The virus was not inactivated by an increase in acidity up to pH 2.46. Allard (3) found that the virus as it occurs in tobacco was very resistant to acids and sensitive to NaOH.

The inactivation of the virus by increasing the alkalinity of the preparation might be explained by assuming that the virus or virus-bearing particles are negatively charged, an explanation which is substantiated by cataphoresis tests to be mentioned later.

TABLE 4.—*Reactivation of mosaic virus by restoring acidity*

H-ion concentration		Plants inoculated	
Original pH	Final pH	Total number	Number mosaic
8.50	8.50	15	0
	8.12	15	6
	7.37	15	13
	5.66	15	14
8.40	8.20	10	0
	8.13	10	0
	8.04	10	0
	7.74	10	1
	5.33	10	6

IN ELECTRIC FIELD MOSAIC VIRUS TENDS TO ACCUMULATE AT POSITIVE POLE

With purified preparations to which dilute KCl was added preliminary cataphoresis tests were carried out in a U tube with a direct current of 110 volts. After the current had passed through the preparation about 6 hours, inoculations were made with specimens of the liquid drawn off from either pole. With one preparation, five tests may be summarized as follows: Only two of the 50 plants inoculated with the liquid from the negative pole developed mosaic, while 37 of the 50 inoculated with the liquid from the

positive pole developed the disease. These results indicate that the virus is carried toward the positive pole, as Olitsky and Hoffman (15) have recently shown, and that the virus or virus-bearing particles are negatively charged.

SUMMARY

Clear and colorless suspensions of the tomato-mosaic virus practically free from the various constituents of the plant juice have been prepared by discarding the liquid from the supercentrifuge and suspending the gummy residue in distilled water, centrifuging again to remove this residue, and clearing and decolorizing the resultant liquid with aluminum-gel acid in reaction.

Virus suspensions thus prepared were still active after passage through Pasteur-Chamberland F filters and 1½ per cent Schleicher and Shüll collodion filters but lost their virulence after passage through an atmometer cylinder, a Pasteur-Chamberland B filter, Schleicher and Shüll 3, 4½, 6, and 7½ per cent collodion filters, and 2, 3, and 5 per cent collodion filters precipitated from solution in equal parts of alcohol and ether. The wash water from the upper surface of used collodion filters was infectious.

The active filtrate from the Pasteur-Chamberland F filters contained about 0.15 per cent of solids.

Virus suspensions stored in a refrigerator, without a preservative added, in general proved to be infectious after 6 to 20 months.

Virus suspensions were inactivated by short exposures to 88° C. and by longer exposures to 82° and 84° C.

The hydrogen-ion concentration of the virus suspensions as prepared was usually about pH 5.0 to pH 6.5. The virus was not inactivated when the acidity was increased to pH 2.46.

When the alkalinity of the virus suspension was increased to about pH 7.5 to pH 8.5, a precipitate was formed and virulence was lost. Virulence was regained, however, when the suspension was made more acid.

When subjected to a cataphoresis test, the virus showed a tendency to be carried to the positive pole. Apparently, the virus or virus-bearing particles are negatively charged.

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HEART ROT OF PINEAPPLE PLANTS[1]

C. P. SIDERIS[2] AND G. E. PAXTON

INTRODUCTION

Young pineapple plants are susceptible to a destructive disease known as heart rot or stem rot. Diseased plants die with the partial or complete destruction of the meristematic tissues of the stem. Losses from this disease in Hawaii vary in different years and show some apparent correlation with abundance of rainfall. The distribution of the disease in the different fields is highly sporadic, certain fields losing from 10 to 30 per cent of their plants and others losing none. Pineapple heart rots have been reported from a number of widely separated countries.

In the Hawaiian Islands, the disease has been attributed by Kunkel (7) to a Phycomycete and by Lyon[3] to Phytophthora. In Jamaica, Ashby (1) obtained a Phytophthora from diseased pineapples, and in Australia a species of Phytophthora also was obtained by J. H. Simmonds (13).

FIG. 1. Healthy and diseased pineapple plants. *a* healthy; *b*, *c*, and *d* diseased, infected with *Phytophthora Meadii*.

[1] Technical Paper No. 12 of the Experiment Station of the Association of Hawaiian Pineapple Canners, University of Hawaii.

[2] Physiologist and formerly Pathologist of the Experiment Station of the Association of Hawaiian Pineapple Canners.

[3] Dr. H. L. Lyon's oral statement to the senior writer.

GENERAL SYMPTOMS OF THE DISEASE

The disease is characterized in the early stages of infection by loss of turgidity and a slight twisting of the central leaves and, in later stages, by the withering and discoloration to yellowish pink and brown. In both early and advanced stages the inner whorls of leaves can be readily detached from the stem by a slight pull, the basal tissues of all such leaves having undergone either a partial or complete disintegration (Fig. 1). Natural falling of these leaves is a frequent late symptom. The stem may also show either a partial or complete disintegration with a characteristic brownish yellow discoloration at the margins between healthy and diseased tissues (Fig. 2).

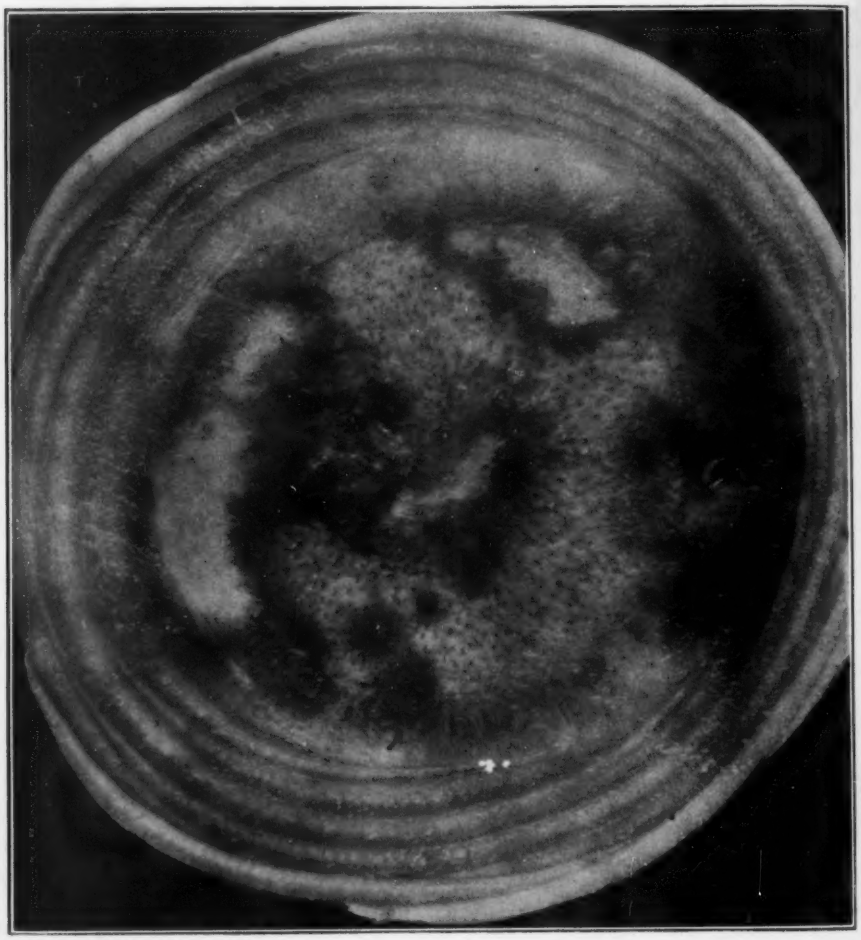

FIG. 2. Cross section of pineapple stem infected with *Pseudopythium phytophthoron*.

The initial infection may appear (1) at the apical end of the stem, (2) at the base of some leaf, (3) at the basal end of the stem, or (4) at the axillary or main roots. The infected tissues soon undergo decomposition. Saprophytic fungi and bacteria may invade such tissues after the initial invasion of the pathogene and cause putrefaction.

THE CAUSAL ORGANISMS

Three organisms were isolated from the diseased tissues of pineapple plants in Hawaii and, on inoculation, reproduced the typical symptoms of the disease. These were *Phytophthora Meadii* MacRae (8), *Ph. melongenae* Sawada (14), and *Pseudopythium phytophthoron* Sideris (12). The culture of *Ph. Meadii* obtained from pineapples is not a typical representative of the species, as comparative studies by the senior writer with an authentic culture[4] have shown. It constitutes a distinct strain distinguishable by a more vigorous development of aerial mycelium. The culture *Ph. melongenae* is a true representative of the authentic or type culture.

These three organisms have been isolated repeatedly from diseased pineapple plants. From the soil they have been isolated only indirectly. Susceptible planting material, tops or crowns, if set deeply enough to cover some of the leaves in soil from infested areas and kept watered to excess, usually will develop the disease. From such plants the fungi are readily isolated in pure culture.

Artificial inoculations with all three organisms were made by placing the inocula at the base of the leaves, on the stem or on the roots of the host grown in root-study boxes (5, 11). Such inoculations were repeated many times and reisolations of the organisms made from resulting diseased tissues. There is no reason to doubt the pathogenicity of these three fungi and their responsibility for the development of heart rot of pineapples.

COMPARATIVE BEHAVIOR OF THE THREE PATHOGENES

The macroscopic symptomatology of heart rot varies but slightly with the three organisms causing it. There are certain differences, of frequent but not constant occurrence, that distinguish the symptoms of heart rot caused by *Pseudopythium phytophthoron* from those caused by *Phytophthora Meadii* and *Ph. melongenae*. These lie in the fact that the former organism makes its initial infection most frequently through the roots and the latter two through the leaf bases. Stem and leaf rot, in the case of *Ps. phytophthoron*, develops after the leaves of the plants have become discolored and flaccid as a result of the destruction of the roots, whereas with *Ph. Meadii* and *Ph. melongenae* both discoloration of the leaves and rotting of

[4] Authentic cultures obtained from Centraal Bureau voor Schimmelcultures, Baarn, Holland.

the stem and leaves develop simultaneously. Consequently, it is possible to recognize the work of *Ps. phytophthoron* under field conditions by the severity of root rot which precedes actual heart rot.

Pseudopythium phytophthoron.—The pathological behavior of this organism is characterized by the wholesale killing of plants through the primary destruction of their root systems. The aerial parts of the plant also become invaded either indirectly, through the initial root infections or, directly, by invasion of the stem through the tender tissues of leaf bases. In cases where the parasite has invaded only the tissues of the roots and not those of the stem, the plants do not develop the characteristic symptoms of heart rot; that is, the leaves do not rot but become discolored and slightly twisted and withered. Typical symptoms of heart rot develop only in cases where the tissues of the stem and leaves have been invaded by the pathogene.

Pseudopythium, apparently, is very limited in its distribution in the Islands. It has been found in only one field, that being in the Waialua district on the Island of Oahu. Its present distribution is limited to an area of apparently 20 acres in that field. Some care has been exercised by the men in charge of this field to keep down the dissemination of the parasite as much as possible. This area, from which the organism was first obtained by the senior writer in 1925, has not grown a successful crop of pineapples since.

Observations in the field have indicated that temperatures below 70° F., together with abundant moisture, favor the development of this disease.

Phytophthora Meadii.—This organism was first obtained from the diseased tissues of pineapple plants by the senior writer in 1925. Since then

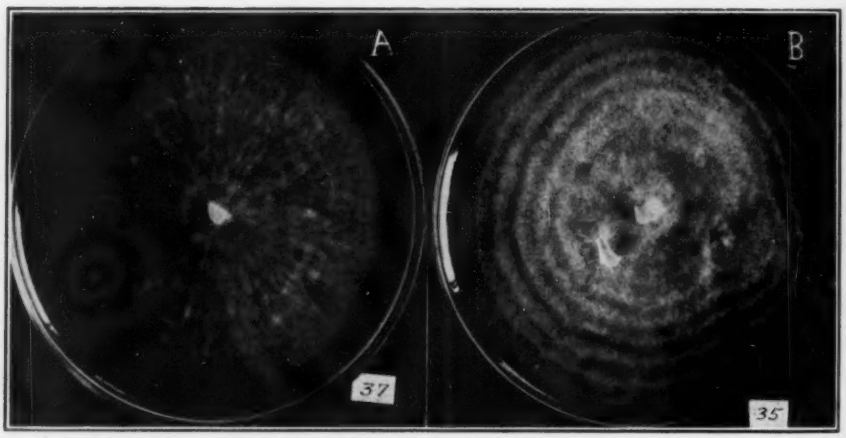

FIG. 3. A. Colony of *Phytophthora Meadii* (pineapple strain) on Carica papaya agar. B. Colony of *Ph. melongenae* on Carica papaya agar.

it has been isolated repeatedly from many localities on the islands of Oahu, Maui, and Molokai of the Hawaiian Archipelago. Of the three organisms studied, this is the one most frequently responsible for the heart rot in these Islands.

This organism produces heart rot chiefly in young plants one week to six months old. Initial invasion may take place through the axils of either basal or apical leaves, through the basal tissues of the stem, or through the

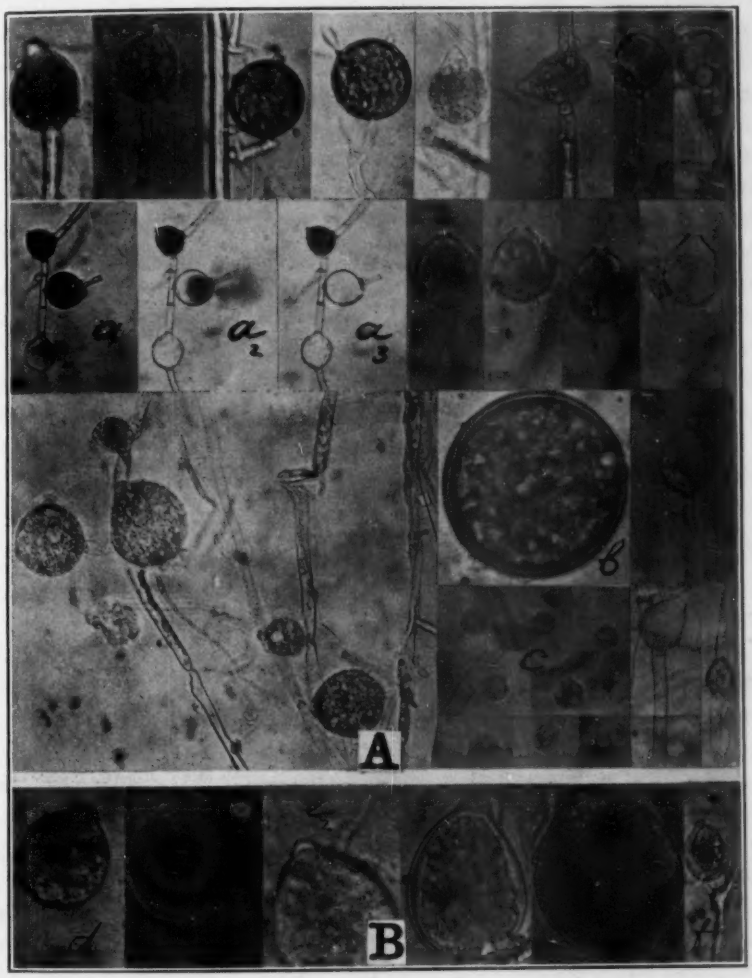

FIG. 4. A. *Phytophthora melongenae*: *a*, germination of zoosporangia (×150); *b*, pseudoconidium or resting spore (×600); *c*, zoospores (×300). Unlabeled illustrations are zoosporangia and euconidia and pseudoconidia (×300). B. *Ph. Meadii*: *d* and *e*, conidia (×600); *f*, conidium (×300).

roots, though the latter path of entry is much less conspicuous than with Pseudopythium. The pathogene lives in the soil and its transfer to leaf axils takes place through the agencies of winds, cultivation implements, and the splashing and overflow of water during heavy rains. In parts of fields where temporary flooding has occurred during heavy rains the disease is more abundant than elsewhere. The fungus, washed with wet soil into the axils of the leaves, is in a favorable position to grow rapidly and invade the tender tissues. The greatest development of the disease occurs during the winter months, which are both cooler and wetter than the summer. The influence of temperature and moisture has not been studied under controlled conditions, but the continued development of the disease in wet fields during the summer months suggests that moisture rather than temperature is the limiting factor.

Phytophthora melongenae.—This organism was first obtained in 1929 by the junior writer from the diseased tissues of pineapple plants grown on the Island of Lanai of the Hawaiian Archipelago. Previous to its isolation from pineapple tissues the senior writer had isolated it from the diseased tissues of *Antirrhinum majus* L. growing in Honolulu, and, on inoculation, it proved pathogenic on roots of *Ananas sativus* Schult.

Extensive studies have shown that this organism is even more aggressively parasitic than *Ph. Meadii*. The pathogenic behavior of these organisms is otherwise very similar, and the resulting symptoms are almost indistinguishable.

OTHER HOSTS OF THE HEART-ROT PATHOGENES

Pseudopythium phytophthoron, being a new organism, has not been studied extensively. *Allium cepa* L. is the only other plant thus far found susceptible.

Phytophthora Meadii was first obtained by MacRae (8) from the diseased tissues of the fruits of *Hevea braziliensis* Muell., causing fruit rot. According to MacRae, the organism is exceedingly destructive during very high humidity. Ashby (2) considers *Ph. arecae* (Colem.) Pethyb. a strain of *Ph. Meadii* and not a distinct species, both organisms occurring in the same geographical area. *Ph. arecae* has been obtained by Coleman from the diseased tissues of the leaves of *Areca catechu* L. or betel nut palm.

Phytophthora melongenae (14) was first obtained by its discoverer from the diseased tissues of the fruit of eggplant, *Solanum melongenae* L. Sawada found that not only the Formosan white eggplant but all other Japanese varieties are susceptible to this disease. Inoculation tests by the same investigator proved that *Ficus carica* L., *Areca catechu*, *Hibiscus esculentus* L., *Epiphyllum truncatum* Haw., and *Ricinus communis* are hosts to this fungus. Oefemia (9) found the same organism in the Philip-

pine Islands to be very destructive to eggplant and, on inoculation, obtained positive proof of its pathogenicity on the bark of *Citrus maxima* Merrill (pomelo), *Capsicum annuum* L. (pepper), *Lycopersicum esculentum* Mill. (tomato), *Lactuca sativa* L. (lettuce), and *Solanum tuberosum* L. (potato). The senior writer found that *Allium cepa* is susceptible to root rot by all three organisms above mentioned.

Pethybridge and Lafferty (10) have suggested that *Ph. melongenae* and *Ph. terrestris* Sherb. be struck out as independent species and incorporated with *Ph. parasitica* Dastur. Godfrey (6) is in agreement with this. Ashby (2), taking the same point of view, suggested that *Ph. melongenae* and *Ph. allii* Sawada be incorporated with *Ph. parasitica*. *Ph. melongenae* doubtless constitutes a distinct variety of *Ph. parasitica* (3) if not a distinct species and the incorporation as suggested may not be a very wise one. If we consider *Ph. parasitica*, however, identical with *Ph. melongenae* then the number of hosts will be increased considerably. Ashby (1) found *Ph. parasitica* in Jamaica causing leaf-stalk rot of the cocoanut palm and two other closely related varieties of Phytophthora causing rots in tobacco and pineapples. Dastur (3, 4) has obtained his organism from castor beans (*Ricinus communis*) and from *Vinca rosea* L., where it was found first causing leaf-rot disease. Godfrey (6) found that *Ph. parasitica* var. *rhei*, an organism closely related to the pineapple parasites, causes root and crown rot of rhubarb (*Rheum rhaponticum* L.).

This brief summary of diseases caused by *Ph. Meadii* and *Ph. melongenae* indicates that the number of hosts may be greater than heretofore suspected.

PROPHYLAXIS AND CONTROL

Studies conducted for the control of this disease so far have given inconclusive results. The only recommendation, based mostly on observations made in areas where the disease occurs, is the adoption of the high-bed system of planting. This is effective in preventing flooding of the plants and decreases quite appreciably the chances of infection. Also, the proper draining of fields reduces the losses from this disease quite appreciably.

SUMMARY

The disease of pineapple plants in Hawaii known as heart rot or stem rot may be caused by any one of three different organisms, namely, *Phytophthora Meadii*, *Ph. melongenae*, or *Pseudopythium phytophthoron*.

The different organisms may invade the stem through its basal tissues, roots, or leaf axils, the ultimate result being the disintegration of the meristematic and juvenile tissues and leaf fall. Heavy rains, causing partial flooding of plants, favor the development of this disease.

Partial control of the disease may be obtained by planting in high beds to avoid flooding during very heavy rains.

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THE FUNGICIDAL ACTION OF ULTRA-VIOLET RADIATION

W. A. R. Dillon Weston and E. T. Halnan[1]

It is the purpose of this paper to describe some recent work on the action of ultra-violet light on some specific fungi. At the time this work was initiated the writers were unaware that Fulton[2] had progressed so far in his experiments. Since, however, it is thought that some useful purpose will be served by outlining the work that we have recently carried out, the following resumé is here presented.

EXPERIMENTAL PROCEDURE

Source of light.—The lamp used was a quartz mercury-vapor lamp (Hanovia Artificial Alpine Sun, 2.5 amp. 210 v. direct-current type). The intensity of the light produced was roughly calibrated at intervals by means of the Erythema Dosimeter as devised by P. Keller.

Materials.—Potato agar was used as a medium for culturing the fungi that were selected for experiment. Eighteen petri dishes were used to contain this. The top cover was replaced, however, by a special form of glass, either Vita glass or Sanalux glass being used for this purpose. The medium was inoculated with the appropriate fungus from pure culture, a needle being used to introduce the organism. These dishes were irradiated for different periods and then compared with controls. The latter were similar cultures made in the same way but either with the ordinary petri dish cover or Sanalux or Vita glass for coverings. They were not irradiated.

Preliminary experiments.—The following fungi were selected for experiment: *Mucor Mucedo* L., *Rhizopus nigricans* Ehr., *Sporodinia grandis* Link, *Cladosporium herbarum* (Pers.) Link, *Dematium pullulans* de Bary and Löw, *Pleospora herbarum* (Pers.) Rabh., *Neurospora sitophila* Shear and Stev., *Fusarium* sp., *Sclerotinia trifoliorum* Eriks., and *Stereum purpureum* Pers. Cultures of these were made and on the same day radiation was commenced. In these preliminary experiments, they were irradiated for 9 minutes a day (this corresponds to 2 A.S.U.), the treatment being continued daily for a fortnight in the case of *Mucor Mucedo, Fusarium* sp. *Stereum pupureum,* and *Sclerotinia trifoliorum.* The difference between the irradiated plates and the controls was most marked. This is well illustrated in figure 1, A, B, C, and D, for Mucor and Fusarium. In both cases the mycelium has the appearance of "shrinking" away from the light. Actually, it does

[1] The writers are indebted to Mr. C. W. Williamson for the photographs of the plate cultures and to Mr. W. E. Dant for assistance in the preparation of material.

[2] Fulton, H. R. The fungicidal action of ultra-violet radiation. Jour. Agr. Research. 38: 159–168. 1929.

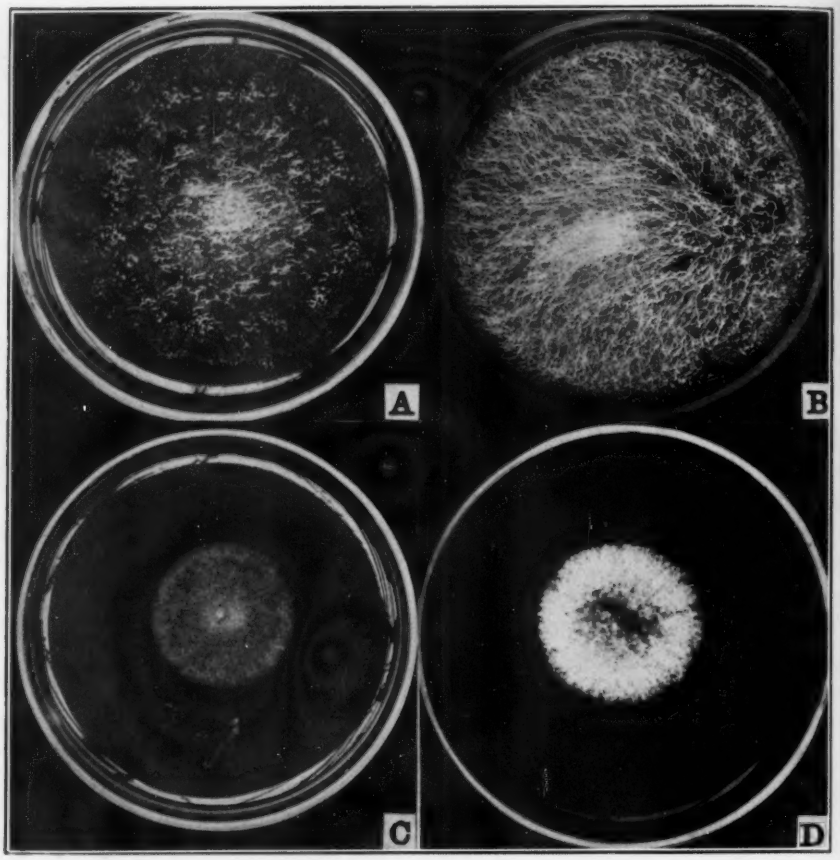

FIG. 1. A. *Mucor mucedo.* Radiated. B. *Mucor mucedo.* Not radiated. C. *Fusarium* sp. Radiated. D. *Fusarium* sp. Not radiated.

grow down farther into the medium, as if hiding from the light; consequently, aerial development is retarded and the sporangiophores and conidiophores appear stunted. After 7 days treatment these plates were reversed and treatment continued for another 7 days (*i.e.*, the plate receiving ultra-violet light was kept as the control and the control was illuminated). The effect of this treatment was to inhibit the growth of the original controls and to encourage growth in the cultures that had originally been retarded by the action of the light. This point is illustrated in figure 2, A, B, C, and D, the same plates as those shown in figure 1, A, B, C, and D, the difference of treatment being as stated, namely, that the former controls had been given light and the ultra-violet cultures had been kept as controls.

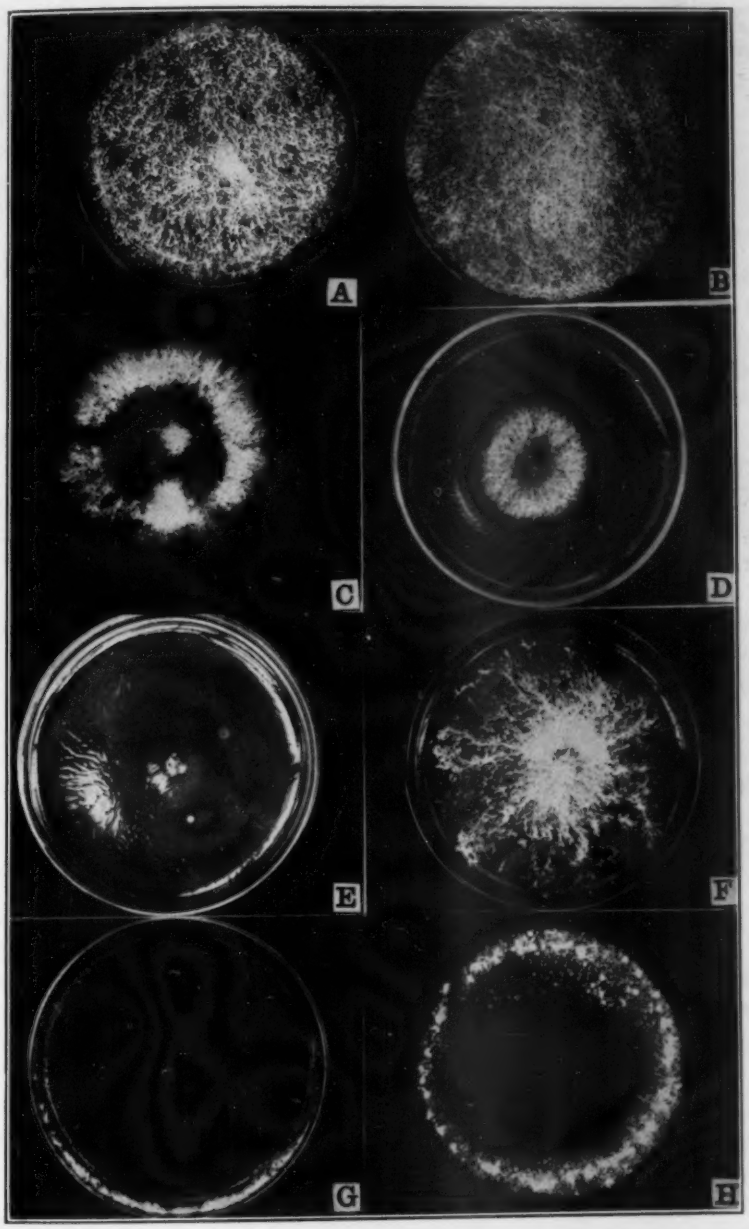

FIG. 2. A. *Mucor mucedo* (see Fig. 1, A). Following nonirradiation. B. *Mucor mucedo* (see Fig. 1, B). Following radiation. C. *Fusarium* sp. (see Fig. 1, C). Following nonirradiation. D. *Fusarium* sp. (see Fig. 1, D). Following radiation. E. *Stereum purpureum*. Radiated. F. *Stereum purpureum*. Not radiated. G. *Sclerotinia trifoliorum*. Radiation. H. *Sclerotinia trifoliorum*. No radiation.

This experiment suggests that in these cases the mycelium is not killed by the light but that growth is inhibited. Fulton,[3] on the other hand, asserts that the mycelium from germinated spores is more easily killed than the resting spores. Our results indicate the probability that in many cases the mycelium may not be killed but rendered dormant for some considerable time. Further experiments to be described will give more evidence on this point.

The effect of ultra-violet light given for 9 minutes per day for 14 days on *Stereum purpureum* was to check further growth and the inference then was that the mycelium had been killed. Figure 2, E and F, illustrates this point: Under similar conditions the rate of growth of *Sclerotinia trifoliorum* was checked, but at the end of the 14 days sclerotia were forming. With this fungus it was interesting to note that, when irradiated with ultra-violet light, the sclerotia were formed at the side of the dish, whereas in the control dishes they were formed much farther away from the side. In both fungi the mycelium grew well down into the medium away from the surfaces. Indeed, in all cases that were dealt with subsequently this was our experience. Figure 2, G and H, illustrates this phenomenon. The plates were photographed after 7 days.

With the other fungi that have been quoted similar results were obtained. Eventually, growth was checked and it was inferred that the mycelium had been killed. This was attributed to the fungicidal power of ultra-violet light. It was noted that the darker colored spores seemed to possess more resistance to light, thus confirming Fulton's observations.

In addition to these fungi, the action of ultra-violet light was tested on the chlamydospores of *Tilletia caries* Tul. produced on Chinese White wheat. The spores were placed on potato-agar medium in petri dishes; the plates intended for irradiation were covered with Sanalux glass. The controls had the normal petri dish cover. The controls were not irradiated, the others being given 9 minutes per day for a week. In the controls the majority of the bunt spores had formed primary conidia, in the case of those radiated; however, development had been checked and few primary conidia were observed.

To confirm the above general findings, 25 watch glasses were half filled with potato agar and then inoculated with *Mucor Mucedo*. A Vita glass plate was placed over these and four strips of carbon paper were pasted on the glass. The cultures were then irradiated for 9 minutes daily for a week with the result that where the watch glasses were covered with the strips of paper growth took place in a perfectly normal manner, but, where they were not covered, very little growth was apparent to the naked eye.

[3] *Loc. cit.*

At this stage preliminary experiments also were started on the action of ultra-violet rays on insects and other minute animals. Saprophytic eelworms from diseased Darwin tulips were placed in water in a watch glass. After one exposure of 9 minutes the majority of the adult eelworms were killed. In somewhat similar experiments the same results were obtained. Work in this direction is now progressing and the results will be communicated in due course.

EXPERIMENTS OF A MORE CONCLUSIVE CHARACTER

Nineteen petri dishes that had previously been exposed for spore-trapping experiments in the air, at altitudes varying from 500 to 13,000 feet, were taken. The contaminations of these were plotted and diagrams of the plates were made. The plates were then exposed for 15 minutes at one foot from the light. One exposure was made with the dish covers removed so that the light was cast directly on the naked culture. Subsequently the contaminations were again plotted and diagrams made when it was noted that the various colonies had not been killed but that more colonies had grown and pre-existing colonies were extending.

ACTION OF ULTRA-VIOLET LIGHT ON STEREUM PURPUREUM

Cultures of *Stereum purpureum* were made on potato agar in 8-cm. petri dishes with Sanalux glass tops. After a lapse of 6 days, in order to allow the fungus to establish itself on the medium, irradiation was commenced. Two series of cultures were irradiated daily, one series at 12 inches from the lamp, the other at 24 inches from the lamp. In each series separate cultures were exposed to the lamp at the following time intervals, 1 minute, 2 minutes, 4, 8, 16, 32, and 64 minutes, respectively. Radiation in this manner was given for 7 days, then the light treatment was stopped. From the records of growth made, it was observed that "the fungicidal action" of the light varied with the time given and the distance away from the lamp. This appeared to confirm Fulton's work; namely, "the killing effect of ultra-violet rays is increased with the lengthening of the time of action and also with the increase in the intensity of the radiation. Decrease in the distance from the source of radiation results in increase in intensity and in consequent killing effect."

In our own experiments we at first inferred that the mycelium had been killed. Subsequent examination 7 days later showed that in each case the fungus had grown and the rate of growth was in proportion to the time of exposure and the distance from the lamp. The mycelium had not been killed, but growth had been checked to the minimum and the fungus had grown away from the light and deep into the medium. Indeed, this could be observed in some cases at the bottom of the petri dish.

THE ACTION OF ULTRA-VIOLET LIGHT ON SCLEROTINIA TRIFOLIORUM

The experiment was designed in exactly the same way as the previous one, and the findings were the same. In this and the preceding experiment the control dishes with the ordinary covers had developed normally. For work of this description this fungus is an excellent one, as the rate of growth can easily be determined by the formation of sclerotia. In no case, however, was the mycelium killed. When light radiation ceased, growth was renewed and, as stated, the rate of new growth was in proportion to the time and distance of the previous exposure. It was again interesting to note that, when under the influence of light, the formation of sclerotia took place at the side of the dish.

DISCUSSION

When these results are compared with those obtained by Fulton the following points must be borne in mind.

Fulton made his exposures with the glass tops removed; whereas, in these experiments Sanalux or Vita glass covers were used and these glasses transmit only 50 to 70 per cent of ultra-violet light. Again, Fulton inoculated his media by flooding the surface with spores or by blowing them on with an atomizer, *i.e.*, by surface inoculation only. In our experiments nearly all inoculations were made with a needle, so that spores and mycelium would be carried *into* the medium. Stevens[4] found that the minimum lethal dosage for exposed spores of *Glomerella cingulata* (Stonem.) S. and v. S. was somewhat above 10 but under 15 seconds, while, for spores covered by an agar layer about 15 mm. deep, the lethal period was over 90 seconds.

In our own experiments we at first thought the mycelium had been killed but, later, as we have shown, we realized that the mycelium was not dead but had been gradually checked in its growth and then rendered dormant. In all cases the mycelium grew deep into the medium to avoid the light. This is interesting since, in laboratory experiments that were carried out with *Mucor mucedo* grown in the normal way in petri dishes, the fungus grew towards the light. For example, a culture was made and a piece of carbon paper was pasted on the dish cover. A circular piece was cut from the middle of this disc. Later, it was found that the fungus had grown towards that portion not shaded by the paper. It is clear, therefore, that the different rays of light must have a different effect upon fungal growth.

[4] Stevens, F. L. Effects of ultra-violet rays on various fungi. Bot. Gaz. 86: 210–225. 1928.

It is here suggested that the higher fungi such as many of those in the Basidiomycetes—excluding the Uredinales and Ustilaginales—are intolerant of ultra-violet light and grow better when this is absent. It is an age-old superstition that "mushrooms," for example, grow only in the dark. These fructifications are formed more in the autumn, winter, and spring. It is generally agreed that growth of these and similar fructifications depends very largely upon moisture. It is, however, here further suggested that in damp and wet weather ultra-violet light is at its minimum and, consequently, growth is not inhibited.

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THE EFFECT OF BORON ON POWDERY MILDEW AND SPOT BLOTCH OF BARLEY

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The research results here reported show that boron may materially influence the susceptibility of barley to powdery mildew, *Erysiphe graminis*, and the spot-blotch disease, caused by *Helminthosporium sativum* P., K., and B. It has been frequently reported that the relative abundance of different soil elements or the character of a nutrient solution affects the development of plant pathogenes. Very little attention has been given, however, to the effect on parasitic fungi of those elements which in small amounts are now recognized as of great importance to the growth of higher plants. In view of the essential character of some of these elements and of the influence which they may have upon the development, structure, and composition of the host, it is perhaps to be expected that outstanding examples should be found in which the effects of such elements are extended to the parasites for which the host plant is the substratum.

Boron is now regarded as essential to many, if not all, of the higher plants, but it is likewise well established that this element may be toxic when supplied in relatively small amounts. The more sensitive plants are injured by concentrations as low as 3 or 4 p.p.m. in culture solutions, whereas other plants may not only tolerate but actually be benefited by concentrations as high as 15 or 20 p.p.m. A plant grown in a solution with a trace of boron supplied as an impurity with other chemicals may be expected to contain upward to perhaps 60 p.p.m. of boron in its dry tissue, whereas, with 15 to 25 p.p.m. in the culture solution, it may contain as little as 200 p.p.m. of boron or upward to 1,500 or even 2,500 p.p.m. The amount of boron found in plant tissue is relative not only to the variety of the plant but also to the stage of maturity and to the secondary environmental factors. The frequency of renewal of cultural solutions, containing boron only as an impurity from other chemicals, materially affects the amount of boron plants contain and, consequently, the severity of the symptoms resulting from boron deficiencies. These facts are mentioned for the purpose of indicating the diversity of conditions with respect to boron concentrations that a parasite may encounter within plant tissue.

EXPERIMENTAL METHODS

Barley, together with some 15 or 20 other plants, was grown in 18-inch rows in each of five beds of clean quartz sand. These beds, constructed of galvanized iron, were so arranged as to make it possible to flush and drain the sand daily with nutrient solutions. The nutrient solution employed

contained calcium nitrate, magnesium sulphate, and potassium acid phosphate in concentrations of 6, 3, and 3 millimoles per liter, respectively, and, in addition, ½ p.p.m. of manganese as magnesium chloride. One ml. of a 5 per cent iron tartrate solution was added to each liter of culture solution. Boron as boric acid was added to this solution to give concentrations of 0, 5, 10, 15, and 25 p.p.m. in the different beds. The solution designated as 0 boron contained in the order of 0.02 p.p.m. of boron derived as an impurity from the C. P. chemicals used. After having reused the solutions for 7 or 8 successive days they were discarded and new solutions substituted.

California common barley and Onas wheat were grown in the summer of 1929 and again in the winter of 1929–30.

RESULTS

After having planted the summer crop of barley on May 22, a differential development of powdery mildew and spot blotch was noted in the different beds by the middle of June. This difference in the severity of attack became pronounced by the latter part of the month, and on July 4 specimen plants of both the wheat and barley were forwarded to Prof. W. W. Mackie at Berkeley for identification of the pathogenes and for such comment as to the severity of attack as the material would permit. Professor Mackie's reply was as follows:

"On my return from my annual vacation I found your letter of July 4, together with the specimens of barley and wheat grown in boron cultures. An inspection of the materials reveals the following:

Barley	Boron	0	p.p.m.	Mildew	4	Spot	Blotch	0
"	"	5	"	"	0	"	"	1
"	"	10	"	"	0	"	"	3
"	"	15	"	"	0	"	"	4
"	"	25	"	"	0	"	"	4

"The barley plants showed a very marked influence of boron upon the diseases. It seems from an inspection of the dried plants, which were not in a fresh condition, that spot blotch, *Helminthosporium sativum*, is fostered by boron in the plants because the specimens grown without boron in the culture showed no spot blotch, whereas all of the others showed rather heavy infestation. Mildew, which is common on all of our common barley, was found abundant upon the barley grown without boron, but entirely absent on those plants grown in the various boron solutions. It appears, therefore, that spot blotch is favored by boron, whereas mildew is entirely prevented in these specimens by the presence of boron.

"The wheat specimens, which were quite dry, appeared to have evidence of insect attack, but I was unable, owing to the condition of the specimens, to absolutely ascertain whether or not small traces of fungus diseases were present.

"The scale which I use varies from zero to 4, zero being no attack and 4 being maximum or heaviest attack of the fungus disease, as represented by the lesions."

The material sent to Professor Mackie was gathered during the hot part of the summer and it seemed possible that under more favorable conditions mildew might have developed on the barley, to at least a limited extent, in the cultures to which boron had been added. Boron concentrations in soil solutions as high as or higher than that in the 5 p.p.m. bed are not of uncommon occurrence under irrigation in California.

The effects of the boron treatments on the boron content of the plants and the combined effects of boron and the pathogenes on the dry weights of 8 plants of both wheat and barley are given in table 1. These plants were pulled from the beds on June 29 while yet quite immature. In agreement with the plant weights obtained from the later cropping of the summer-grown plants and from the subsequent winter plantings the growth of barley was depressed when boron was omitted from the culture solution, whereas no material reduction in weight occurred with wheat.

TABLE 1.—*Dry weights and boron content of 8 plants of barley and wheat grown in sand cultures from May 22 to June 29, 1930. Analyses by L. V. Wilcox*

Boron added to culture solutions, p.p.m.		0	5	10	15	25
Dry weight of plants, gms.	barley	16.3	20.8	16.2	12.7	11.0
" " " " "	wheat	10.6	11.1	8.3	8.2	6.2
Boron on dry weights, p.p.m.	barley	57	348	646	1045	1349
" " " " "	wheat	24	311	748	1058	1546

The winter plantings of barley and wheat were made on October 4, 1929. In agreement with the observations made on the summer planting, no evidence of the spot-blotch disease appeared on the barley plants in the 0 boron bed. If spot blotch was present it was so masked in its macroscopic appearance by the presence of mildew that it could not be identified as late as the middle of April. In the beds with 5, 10, 15, and 25 p.p.m. of boron, the spot blotch was abundant and of approximately equal severity under each of the four treatments.

In this winter planting of barley, powdery mildew was the most abundant on the plants receiving no boron, but it attacked plants in all of the

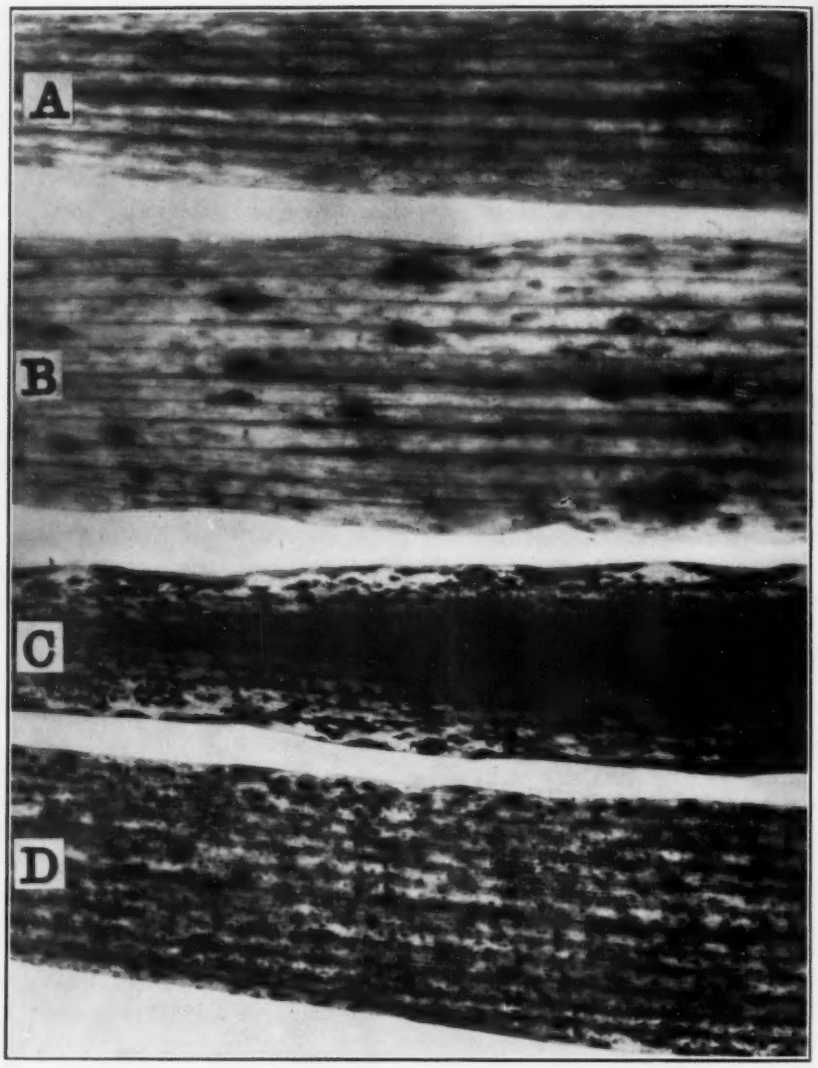

FIG. 1. Leaves of barley plants grown in sand cultures. A and B, from plants grown without boron and severely attached by powdery mildew, spot blotch being absent. C and D, from plants grown with 5 p.p.m. of boron. The latter were heavily attacked with spot blotch but some mildew also was present. B and D were the older and were largely devoid of chlorophyll. X 2½ approximately. March 28, 1930.

other beds to some extent. In the 0 boron bed the mildew was present on all leaves and many were almost covered. In the 5 p.p.m. bed it was also abundant, but the areas covered were smaller and they did not coalesce to the extent they did on the plants receiving no boron. Some leaves without mildew were found. Less mildew occurred on the 10 p.p.m. of boron plants than on those receiving the 5 p.p.m., and the amount was further reduced in the 15 p.p.m. of boron bed. In the 25 p.p.m. of boron bed only two well-shaded leaves on 100 culms were found infected. The differential development of powdery mildew and the spot-blotch disease on barley without boron is illustrated in figure 1.

Powdery mildew was present on the winter-wheat plants irrespective of the amount of boron supplied. In abundance it was approximately equal on all to that on the barley in the 5 p.p.m. bed.

A late winter planting of oats in the same beds was mildly attacked by mildew. Less mildew was present on the oat plants in the higher boron concentration, but the gradient was not so marked as that shown on the barley.

DISCUSSION

Although extreme specificity among the races of the different pathogenic fungi is quite common, it is nevertheless remarkable that the wheat and barley strains of powdery mildew, which attack only their own respective hosts and which in appearance are identical, should in the one case be so markedly influenced by the amount of boron supplied to the host plant and in the other almost uninfluenced by it. This difference in the reactions of the two strains of mildew seems especially noteworthy when it is observed (Table 1) that no material difference was found in the amount of boron in the dried wheat and barley plants.

The decreasing abundance of mildew on the barley as the boron supply was increased has made it appear most logical to place the burden of the interpretation of the foregoing relationship directly on the boron content of the barley plants. The fact that some mildew occurred on plants supplied with large amounts of boron, in the winter planting, and that mildew was abundant on the apparently normal barley supplied with 5 p.p.m. of boron would indicate that the development of mildew was not contingent upon structural abnormalities of the host plant.

Johnston and Dore[1] found an increased accumulation of sugar and starch in the leaves of boron-deficient tomato plants. If such accumulations of sugar and starch occurred in the barley they may have been contributing factors to the luxuriant development of the mildew in the bed with only a

[1] Johnston, Earl S., and W. H. Dore. The influence of boron on the chemical composition and growth of the tomato. Plant Physiol. 4: 31–62. 1929.

trace of boron. It should, however, be mentioned in this connection that Dufrénoy[2] found the plastids of chlorotic areas of citrus leaves affected with toxic quantities of boron gorged with starch. This observation might be taken to indicate that excessive amounts of boron may result also in accumulations of photosynthetic products in leaves.

The results clearly indicate that an amount of boron in barley plants greater than that supplied as impurity in the chemicals used is requisite for the development of the Helminthosporium disease.

SUMMARY

Barley and wheat were grown out of doors in large sands beds flooded daily with nutrient solutions. It was found that the spot blotch of barley, caused by *Helminthosporium sativum*, did not develop when boron was omitted from the culture solution. In a summer planting the abundance of spot blotch was successively increased by 5, 10, and 15 p.p.m. of boron, whereas in a winter planting the severity of the attack was approximately the same in these and the 25 p.p.m. concentrations.

In the summer planting of barley, powdery mildew, caused by *Erysiphe graminis*, was abundant on plants without boron and absent when boron was supplied. In the winter planting some mildew was present under all treatments, being abundant on the plants without boron and present on but two leaves of 100 culms grown with 25 p.p.m. of boron. No mildew developed on summer-grown wheat, but it was moderately and equally abundant on all winter plants, irrespective of the amount of boron supplied.

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[2] Dufrénoy, J. A cytological study of water soluble and fat soluble constituents of citrus. Jour. Agr. Res. 38: 411–429. 1929.

THE SUSCEPTIBILITY OF AMERICAN WHEAT VARIETIES RESISTANT TO TILLETIA TRITICI

I. REICHERT[1]

Those varieties of wheat, such as Ridit, Hussar, Martin and White Odessa, highly resistant to *Tilletia tritici* (Bjerk.) Wint. in the United States, have achieved, in addition to their practical value, considerable importance in elucidating the question of the occurrence of strains in bunt. Faris (1) was certainly the first to adduce experimental evidence of the existence of a difference in the virulence of bunt collections originating in different countries. However, definite light was thrown on this question only after the experiments of Sessous (10), Gaines (2), and especially of Roemer (8), who were the first to break down the exceptional resistance of the American wheat varieties with German collections of bunt and to show decisively the existence of different strains in bunt. Whereas the experiments of Faris (1) and of Stakman and Rodenhiser (6, 7) showed a slight difference in the infective capacity of the collections used, the works of Roemer (8), Reed (3), and Gaines (2), who worked with the above-named resistant varieties, demonstrated a complete difference in the virulence of the bunt collection ranging from entire capacity to entire incapacity for infection. These four bunt-free varieties were thus shown to be excellent indicators for the differentiation of strains of the bunt organism.

As we were experimenting with eight collections of bunt, used by Roemer (8) and Sampson (9), in an effort to infect wheat varieties that had proved to be bunt-free in Palestine (4, 5), we decided to try to infect the four highly resistant American varieties, using them as control plants.

Another object in introducing these resistant American varieties into our experiments was to investigate in Palestine the results obtained by various workers under different climatic conditions. In spite of the evidence adduced by previous investigators for the permanence of the bunt strains in different countries, there are some results contradicting that assumption and showing the marked influence of climatic conditions. To mention only one instance: The Halle-Saale, Germany, collection of *Tilletia tritici* was four times as virulent as the Pullman (Washington) collection on the variety Heils Dickkopf grown in Halle (8). On the other hand, the Halle collection was unable to infect the Heils Dickkopf variety grown at Pullman, whereas the Pullman collection produced 42 per cent infection

[1] The writer wishes to express his sincere thanks to Dr. T. Roemer, Halle-Saale, Germany, and Miss Kathleen Sampson, Aberystwyth, Wales, for their kindness in supplying him with wheat varieties and bunt collections for his experiments.

on Heils Dickkopf grown in Pullman (2). The experiments undertaken are therefore of general interest.

METHODS AND MATERIALS

We used the following four wheat varieties, Ridit, Martin, White Odessa, and Hussar, the first three varieties in two different stocks from Wales and Germany, respectively, making altogether seven stocks of wheat varieties, four of them, Ridit, Hussar, Martin, and White Odessa, provided by Dr. T. Roemer in Halle, Germany, and three varieties, Ridit, Martin, and White Odessa, procured by Miss Kathleen Sampson, in Aberystwyth, Wales.

The following *Tilletia tritici* collections were used: seven received by Dr. Roemer originating in different countries, one by Miss Sampson from Wales and one from Palestine—altogether, nine bunt collections.

The seeds were dusted in a container with *Tilletia tritici* spores taken from wild emmer plants, infected the previous year, and were sown in rows of 50 seeds on December 27, 1928. They were sown 15 cm. apart and spaced 7.5 cm. apart. The soil was sufficiently moist, the rainfall for the last ten days before sowing amounting to 33 mm. Rain fell again three days after sowing and the total amount during the next eight days reached about 80 cm. The temperature was thus reduced to 10° C. at the time of germination.

Many of the young plants, unfortunately, were destroyed by field mice, but the results from the remaining plants are sufficiently symptomatic and worth recording.

THE RESULTS

From the above results we see that the Ridit variety remained resistant to all bunt collections used, with the exception of the Breslau collection, which infected only the German stock up to 4.7 per cent. The high resistance of the Hussar variety was broken only by the Cosel bunt collection. Both stocks of the Martin variety remained immune from all the collections of bunt used. The White Odessa variety showed freedom from infection when inoculated with the Welsh, Pullman (in the Welsh stock), Wageningen, and Palestine bunt collections, slight susceptibility in the German stock to Pullman, and extreme susceptibility in both stocks to the Cosel, Breslau, and Landeskrona bunt collections.

The most virulent bunt collections were those from Cosel and Breslau (from 15 to 28 per cent). The weakest strains were from Palestine, Wales, Wageningen, and Zurich (not tried on all varieties). Pullman produced a slight degree of infection in the German stock of White Odessa, and Landeskrona caused heavy infection of White Odessa (on the German stock 5.2 per cent and on the Welsh 25 per cent).

TABLE 1.—*The percentage of bunted plants obtained in seven stocks of four varieties of wheat inoculated with spores of nine different collections of Tilletia tritici. Experiment conducted at the Experimental Farm, Gevath, Palestine, 1928–29*

Wheat varieties	Origin of the bunt collections									
	Aberystwyth, Wales	Pullman, U. S. A.	Cosel, Germany	Breslau, Germany	Wageningen, Holland	Landeskrona, Sweden	Lyngby, Denmark	Zurich, Switzerland	Gevath, Palestine
Ridit, Wales	0	0	0	....	....	0	....	0	0
Ridit, Germany	0	0	0	4.7	....	0	....	0	0
Hussar	0	0	14.2	....	0	0	....	0	0
Martin, Wales	0	0	0	....	0	0	....	....	0
Martin, Germany	0	0	0	....	0	0	....	....	0
White Odessa, Wales	0	21.2	15.2	0	25.0	25.0	....	....	0
White Odessa, Germany	0	2.1	22.2	28.3	0	5.2	....	....	0

TABLE 2.—*Comparative behavior of eight collections of Tilletia tritici on Ridit, Hussar, Martin, and White Odessa in different countries*

Sources of inoculum	Wheat varieties and percentage of bunted heads											
	Ridit			Hussar			Martin			White Odessa		
	Amer. stock	Welsh stock	Germ. stock	Amer. stock	Welsh stock	Germ. stock	Amer. stock	Welsh stock	Germ. stock	Amer. stock	Welsh stock	Germ. stock
1. *Wales*												
a. in Wales	.....	21.0	.....	.....	4.0	.....	.....	0	.....	.....	6.6	.....
b. " Brooklyn	.....	.....	.....	0	.....	.....	0	.....	.....	0	.....	.....
c. " Palestine	.....	0	0	.....	.....	0	.....	0	0	.....	0	0
2. *Pullman*												
a. in Pullman	0	.....	.....	0	.....	.....	tr.	.....	.....	0	.....	.....
b. " Halle	.....	.....	0	.....	.....	1.0	.....	.....	1.0	.....	.....	8.0
c. " Brooklyn	.....	.....	.....	0	.....	.....	0	.....	.....	0	.....	.....
d. " Palestine	.....	0	0	.....	.....	0	.....	0	0	.....	0	2.1
3. *Cosel*												
a. in Halle	.....	.....	7	.....	.....	50.0	.....	.....	77	.....	.....	83.0
b. " Palestine	.....	0	0	.....	.....	14.2	.....	0	0	.....	21.2	22.2
4. *Breslau*												
a. in Halle	.....	.....	10	.....	.....	46.0	.....	.....	61.0	.....	.....	85.0
b. " Palestine	.....	.....	4.7	.....	.....	.....	.....	.....	.....	.....	15.2	28.3
5. *Wageningen*												
a. in Halle	.....	.....	6.0	.....	.....	0	.....	.....	1	.....	.....	7.0
b. " Palestine	.....	.....	.....	.....	.....	0	.....	0	0	.....	0	0
6. *Landeskrona*												
a. in Halle	.....	.....	1	.....	.....	1	.....	.....	3	.....	.....	2
b. " Palestine	.....	0	0	.....	.....	0	.....	0	0	.....	25.0	5.2
7. *Lyngby*												
a. in Halle	.....	.....	2	.....	.....	19	.....	.....	20	.....	.....	16.0
b. " Palestine	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8. *Zurich*												
a. in Halle	.....	.....	0	.....	.....	0	.....	.....	12.0	.....	.....	4.0
b. " Palestine	.....	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....

A comparison with the results of other countries.—It may be interesting to compare the results obtained in the Palestine experiments with the outcome of similar work in other countries, especially with those of Roemer (8), who used the same wheat varieties and seven bunt collections, as we did, and of Reed (3), who used three of our wheat varieties and two of our bunt collections; and, further, with that of Miss Sampson (9), who used all four wheat varieties and one of our bunt collections.

The above table gives a clear survey of the infective capacity of the eight bunt collections on different stocks of the four American wheat varieties grown under different climatic conditions.

We see that the Welsh bunt infected Ridit in Wales but not in Palestine, even from stock originating in Wales. It was able also to produce slight infection on Hussar in Wales but not at Brooklyn or in Palestine. It behaved similarly on White Odessa. The Martin variety remained immune from the collection in all three countries.

The Pullman bunt was unable to produce infection on Ridit at either Pullman or Halle or in Palestine, where experiments were conducted. When inoculated with the Pullman strain Hussar remained in Pullman, Brooklyn, and Palestine, and was only lightly infected in Halle. The Martin variety also showed a high degree of resistance to the Pullman bunt. In the Brooklyn and Palestine experiments no infection occurred, and in the Pullman and German trials only a very slight amount of infection developed. The American stock of White Odessa was not infected either in Pullman or in Brooklyn. The German stock, however, showed a fair amount of infection both in Germany and in Palestine.

The Cosel bunt collection infected Ridit and Martin in Halle but not in Palestine. It also caused heavy infection in the German stock of Hussar in Halle and in Palestine. Both stocks of White Odessa were severely infected by this collection in both Germany and Palestine.

The Breslau bunt collection gave the same positive results in Germany as in Palestine. Both stocks of White Odessa were heavily infected by this collection in both countries—Germany and Palestine.

The Wageningen bunt collection was unable to infect Hussar either in Germany or in Palestine. Martin and White Odessa were infected by the bunt collected in Germany but, in Palestine, not even the German stock contracted the disease.

The Landeskrona bunt failed to infect Ridit, Hussar, and Martin in Palestine but caused slight infection in Halle, Germany. White Odessa was infected by this collection in Germany as well as in Palestine, more virulently in the latter than in the former country.

The Zurich bunt collection caused no infection on Ridit, either in Palestine or in Germany.

Number of strains.—An attempt may now be made to summarize the differential reaction of the four wheat varieties to the nine collections of bunt, as shown by the results in the different countries. They are more likely to be correct, as they are based on the results obtained under different climatic conditions.

TABLE 3.—*Number of bunt strains based on the susceptibility of Ridit, Hussar, Martin, and White Odessa to nine collections on bunt in different countries*

No. of strain	Name of coll.	Name of the wheat varieties and their + or − susceptibility			
		Ridit	Hussar	Martin	White Odessa
1	Wales	+	+	−	+
2	Pullman	−	+	+	+
3	Cosel	+	+	+	+
	a. Breslau				
	b. Landeskrona				
	c. Lyngby				
4	Wageningen	+	−	+	+
5	Zurich	−	−	+	+
6	Palestine	−	−	−	−

From the above table it is evident that six bunt strains may be differentiated among the nine on the basis of the behavior of the four wheat varieties. Reed (3), who used 21 collections of bunt and five wheat varieties, was able to distinguish only six strains. His strains are not identical with those shown in the above table. It is evident that many more than six strains are known today. The Palestine collection represents a special strain, as shown elsewhere (5).

CONCLUSION

On the whole, the experiments carried out in Palestine confirmed the results obtained by Roemer (8). The bunt collections of Breslau and Cosel, which proved the most virulent in the experiments in Halle (Germany), also maintained their infective capacity in Palestine under quite different climatic conditions. The Welsh, Pullman, Landeskrona, and Zurich collections gave almost identical results in both countries, Germany and Palestine. The Landeskrona collection seemed to have lost some of the virulence it manifested in Germany. A greater loss of virulence was observed in the Cosel bunt when applied to the Ridit and Martin varieties. Very striking is the change in the Welsh bunt, which lost its infective capacity for Ridit,

Hussar, and White Odessa in Wales when employed in the United States (Brooklyn) and in Palestine.

Hardly any difference in reaction to the bunt of the different collections was noticed between the different stocks of the wheat varieties used in Palestine. Only in one out of 16 experiments with both stocks was a slight difference noticed in White Odessa. This is not quite in agreement with Stadler's findings (11).

Such modifications in the virulence of the bunt of certain collections in other countries are difficult to explain. Temperature influence seems to play no part, as an optimum of infection occurred in all experiments. More plausible, perhaps, is the assumption that other climatic conditions are the decisive factors in the change. It must be assumed that these conditions inhibit the germination of the more virulent components of the bunt collection and favor the development of the less virulent ones. Furthermore, the possibility of an alteration in the capacity of the host for resistance should not be excluded, but this hypothesis is considered less probable.

SUMMARY

1. Experiments were carried out to determine the behavior of nine bunt collections towards the Ridit, Hussar, Martin, and White Odessa wheat varieties.

2. On the whole, the results obtained confirmed those of Roemer. The Breslau and Cosel bunt collections proved to be the most virulent and those of Wageningen, Zurich, and Palestine the weakest.

3. The permanence of the virulence in different countries with different climatic conditions was then proved. It must, however, be admitted that modifications are also possible since they occurred in the Welsh bunt collection.

4. Six different strains of bunt were differentiated in the collections used on the basis of their behavior towards the four wheat varieties.

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STRIPE RUST, PUCCINIA GLUMARUM, ON WHEAT IN ARGENTINA

HARRY B. HUMPHREY[1] AND RICHARD O. CROMWELL[2]

Stripe rust, *Puccinia glumarum* (Schm.) Eriks. and Henn., in South America, was first collected there by E. W. D. Holway, in 1919 (1) who found it on *Hordeum chilense* R. and S. at Viña del Mar, Chile. In 1920 he found it at Riobamba, Ecuador, on *Agropyron attenuatum* R. and S. Elsewhere, in South America, it apparently had never been collected until October, 1929, when the junior writer observed it in epiphytotic proportions on wheat in Argentina. He is under the impression that he saw it there in 1926, also, but made neither a collection nor a record of it. While in Argentina in 1929 he had opportunity to make extensive observations on the occurrence and severity of the epiphytotic. Accordingly, a detailed report of his findings was prepared with a view to its ultimate use in the preparation by the senior writer of a somewhat more ample account of stripe rust in the Americas.

Stripe rust has long been recognized as one of the most important cereal diseases known to European agriculture. Its ravages are most severely felt by the farmer who depends upon wheat for a portion or for all of his income. In the United States this rust is, thus far, known to occur only in the Pacific and Intermountain States. Potentially, it is tremendously important to the great wheat-growing regions of the Mississippi Valley and the Eastern States where, by chance, it may some day be introduced through transportation of crop products or otherwise from parts of the world subject to stripe-rust epiphytotics.

The occurrence of stripe rust in the Western Hemisphere was discovered on wheat in Arizona by F. Kølpin Ravn (4), in 1915, while touring the United States as a guest of the Department of Agriculture. Further research by the senior writer *et al.* (5) disclosed the fact that this rust had first been collected in the United States by Piper, in 1892, on *Elymus glaucus* Buckl. and *Bromus carinatus hookerianus* (Thurb.) Shear. It was later collected by E. and E. T. Bartholomew on *Sitanion hystrix* (Nutt.) J. G. Smith. These early collections of *Puccinia glumarum* were, however, not recognized as stripe rust but were assigned to *P. agropyri* and *P. rubigovera* where they remained until 1922, when they were correctly identified by the senior writer. In 1896 it was collected by Holway on *Hordeum jubatum* L., near Mexico City, Mex., and assigned to the species *P. rubigo-*

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vera. None of these early collectors recorded the occurrence of this rust or made any collections of it on wheat or other cultivated host.

Since its discovery in North America by Ravn stripe rust has been collected widely throughout the Pacific and Intermountain States, excepting New Mexico and Nevada, and was observed in August, 1919, as far east as Newell, S. Dak. In western Canada it is more or less prevalent on wheat and certain congenial grass hosts in Vancouver Island and elsewhere in British Columbia, and to a limited extent in Alberta and western Saskatchewan. Stripe rust occurs rather commonly and sometimes devastatingly in Mexico, where it has been observed in the Yaqui Valley and certain other important wheat areas as far north and east as Monterey. Its presence in Mexico and apparent absence from Texas have puzzled us not a little in attempting to account for the possible Mexican source of certain physiologic forms of *P. graminis tritici* Eriks. and Henn. Its failure to establish itself in near-by Texas may possibly be explained in part by the fact that the prevailing winds that move across the northern half of Mexico during April, May, and June, according to Bartholomew and Herbertson (2) and the more recent unpublished studies of the senior writer, blow from the southeast and east to northwest rather than from the south. This fact also may in part account for the general prevalence of *P. glumarum* in Arizona and California.

The late Dr. Carlos Spegazzini of La Plata, Argentina, collected extensively and with more than usual thoroughness the rusts and other fungi of Argentina over a period of 42 years, or from 1880 to 1922. During that time he published 19 papers, or a total of nearly 2,500 pages; yet, not once does he record the occurrence of *P. glumarum* in Argentina. Other collectors and students of the rusts of South America, such as Gustav Gassner, P. Hennings, E. Ule, and others, failed either to observe or record the presence of stripe rust east of the Andes. Arthur (1) states that there are certain collections recorded under the names *P. rubigo-vera, P. sessilis, P. straminis,* etc., that he has not yet seen. The examination of these and other South American collections may yet disclose the presence of *P. glumarum* beyond the confines of Ecuador and Chile.

The junior writer's 1929 observations on the conditions affecting the wheat crop of Argentina covered approximately 80 per cent of the total wheat acreage. His field inspections began near the northern limits of the main wheat belt, in the Provinces of Santa Fé and Cordoba, in October, and progressed southward to near the southern limits of the belt, in southern Buenos Aires Province and Territory of Pampa, through November. This allowed each locality to be observed while the wheat was in the blossom-to-milk stage of development.

The severe epiphytotic of stripe rust in the territory covered was confined roughly to the area encompassed by Salliquelo, Colonel Suarez, Tres Arroyos, Necochea, and Tandil in the southern part of the Province of Buenos Aires and comprised about 40,000 square miles. East of the above area to the coast was not inspected because the wheat acreage is extremely light there. For the same reason an area east of a line—Buenos Aires City to Bragado, Bolivar, La Madrid, Rauch, and Maypu—was not seen. From reports, however, it was assumed that stripe-rust infection was moderate to severe wherever wheat was grown in either of these eastern areas. As one proceeded to the north or west from the seacoast the amount of this rust diminished until it became light or none at the northern and western borders of the Province and beyond. There was a trace of it in parts of southern Santa Fé. Likewise, drouth greatly affected wheat in the remainder of this Province. Cordoba's wheat crop was almost a failure from drouth, and the Province was visited under such conditions that it is impossible to report more definitely than to state that the disease was nearly, if not quite, absent. The extreme west-central part of the Province of Buenos Aires, around Maza, Rivera, Puan, Alta Vista, Villa Iris, and especially west thereof, was scarcely affected, for the early-season drouth resulted in a poor plant growth. In this region, where Kanred is popular, the average yield approximated two bushels per acre. At the new Southern Railway experimental farm, Bordenave, Buenos Aires, a trace of stripe rust was seen.

In the Tres Arroyos territory there were two optimum periods for the development of *P. glumarum*. A heavy infection killed the lower leaves during the boot-to-blossom stage of the host. Then the rust seemed for a time inactive only later to resume the attack and kill the remaining leaves during the milk stage of kernel development. This final attack was severe also on the glumes, awns, and kernels of susceptible varieties. Markedly noticeable differences in what may have been varietal susceptibility were observed in several varieties.

The weather at Tres Arroyos during the life of the 1929 crop is of interest because the stripe-rust epiphytotic was as severe there as anywhere within the area visited. Precipitation for 1928 is given but a record of the temperatures for that year was not available. In the Tres Arroyos district wheat is sown from late May to early August and harvested in December and January.

Table 1 shows that the October precipitation was 75 millimeters in excess of normal. It was near the end of October and the beginning of November when the epiphytotic of *P. glumarum* appeared. Temperatures had not been unfavorable. Early wheat was beginning to head about Octo-

TABLE 1.—*Monthly precipitation for 1928, precipitation and maximum and minimum temperature for the first 11 months of 1929, and the normal average and actual average temperature for the period of June to November, 1929, inclusive, at Tres Arroyos, Province of Buenos Aires*[a]

Month	Precipitation in millimeters			Temperature (degrees C.)			
				1929			
	1928	Normal	1929	Max.	Norm. av.	Actual av.	Min.
Jan.	10.5	65.0	66.0	38			4
Feb.	161.0	74.0	92.5	37			5
Mar.	34.0	68.0	18.0	35			1
Apr.	177.0	36.0	73.0	30			0
May	48.0	32.0	53.5	21			-1
June	20.5	35.0	45.0	17	8.2	8.0	-3
July	41.0	40.0	7.0	20	7.7	8.1	-3
Aug.	2.0	33.0	15.0	21	8.7	9.2	-4
Sept.	5.0	51.0	55.0	28	11.0	10.8	-3
Oct.	58.5	63.0	138.0	36	13.7	12.5	-3
Nov.	55.0	58.0	41.0	38	17.0	18.8	4
Dec.	8.0	72.0	.....	.....	.....	.....	.....
Total	620.5	627.0	604.0				

[a] Jan. to June are Experimental Farm unofficial figures except normals, which are official. July to Dec. are official.

ber 21. Four weeks of favorable rust weather was sufficient to bring about the full natural development of a severe rust epiphytotic, and the abundant rainfall of October undoubtedly promoted its development during the critical period of the wheat plant's growth. The records have been searched to learn in what other years the precipitation in October and November exceeded the normal to an approximate degree, and it has been found, as indicated in table 2, that the moisture and temperature conditions for the period in question were sufficiently favorable in 1920 and 1922 to have produced an epiphytotic of stripe rust provided enough inoculum had survived the rigors of the preceding winter months. There is, however, no record of the presence of this rust in Argentina in those years.

Other factors necessary to an outbreak of *P. glumarum* on winter wheat (6) include conditions favorable to infection and spread during the fall (late April, May, June, in southern Buenos Aires) and early spring (end of August and September). At Tres Arroyos there was sufficient rainfall, apparently, to favor spread of stripe rust while wheat was young in the fall and subsequent early spring. The year 1928 produced a good crop with autumn moisture comparable to that of 1929, scant in early spring, and normal thereafter. There was no noticeable rust damage of any kind.

TABLE 2.—*Monthly precipitation and mean monthly temperature for the years 1920 and 1922, respectively, at Tres Arroyos, Province of Buenos Aires*

Month	Precipitation in millimeters		Temperature (degrees C.)			
			1920		1922	
	1920	1922	Mean max.	Mean min.	Mean max.	Mean min.
Jan.	42	143	31.1	13.6	31.0	14.4
Feb.	66	100	29.2	13.0	27.8	12.1
Mar.	40	43	28.2	13.4	26.9	11.9
Apr.	112	54	23.3	10.0	21.3	7.4
May	2	23	17.9	6.3	17.7	6.0
June	5	125	13.0	1.0	10.4	2.8
July	48	26	12.1	0.8	14.3	6.0
Aug.	5	19	17.0	2.6	14.2	2.6
Sept.	71	21	18.7	4.9	19.1	4.7
Oct.	107	94	18.7	7.7	17.5	6.4
Nov.	67	146	23.8	10.0	25.3	10.9
Dec.	202	60	27.8	12.6	30.4	12.2
Total	767	854				

Argentina's better-seed campaign probably has imported more lots of seed wheat since 1925 than at any time in the last three decades. These imports increased annually during the period 1925 to 1928. Government and railroad multiplication and distribution of these imports and of varieties bred locally by 1929 brought about almost a complete change of varieties grown throughout the nation from those grown in 1925. In view of this fact there is a possibility, if not probability, that the sporadic outbreak of stripe rust in Argentina may have had its origin through spores brought in on plant material in shipments of wheat received from European sources. Hungerford (6) has shown that the urediniospores of this rust retain their germinability two to three months under normal conditions, and Becker (3) has established the fact that under conditions of refrigeration they are germinable after 430 days.

The potential importance of stripe rust to cereal culture in the major wheat-producing areas of the Americas is so great as to warrant a thorough and comprehensive investigation of the problem. Much as has already been contributed to our knowledge of this rust there yet remains a great deal to be learned about its epiphytology, its possible methods of introduction into new areas, its physiologic specialization, life history, and control.

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FROST-TOLERANT AND BLIGHT-RESISTANT POTATOES

DONALD REDDICK

FROST TOLERANCE

In such a warm, dry season as existed in most of the northern potato regions during the summer of 1929, the potato makes very little growth until the rainy, cool days of September arrive. It is in such years that early frost is most unwelcome. Ten days or two weeks of growth under favorable conditions may make an enormous difference in the yield of No. 1 tubers. Likewise, a January frost in the Southern States may injure the young plants and thus delay the harvest. In 1929, in New York, killing frost occurred on September 20 and 21 throughout most of the potato sections, but this was followed very generally by fourteen to twenty days of weather very favorable for tuber production. At Ithaca the official record of the U. S. Weather Bureau for each of these nights was 29° F. (−2° C.). Unfortunately, there were no thermometers present in the potato plot in which the following observations were made on these nights. The plot is about one mile distant from the recording station and usually runs about 1° F. colder at night than the official record.

It was not surprising to find in the experimental plot some plants that had withstood with no injury whatever two successive nights of 29° or slightly colder, because there were present in the field plants of *Solanum demissum* Lindl., seeds of which were kindly supplied to me by Dr. C. F. Clark. *S. demissum* is reported as an herbaceous perennial from the mountains of Mexico at 8,000 to 9,000 feet (Uhde). From his recent paper it is clear that Salaman (9)[1] is concerned with this same species although he uses the later name *utile* Klotzsch. Rydberg (8) regards the two as identical and even Bitter (1),[2] regards the two as very close and suggests that further study may show them to be identical. *S. utile* is likewise reported from Mexico (Rio Frio, at about 10,000 feet, and from Michoacan, at about 8,000 feet). It is even possible that the original material on which the species is founded is identical. The same collector is cited, Mr. C. A. Uhde, "a German gentleman, who has resided for many years in the west of Mexico," and the same general locality is also recorded. Lindley (6) quotes as follows: "Native Mexican potatoes, growing at 8000 to 9000 feet elevation" while Klotzsch (4) secured seeds from the director of the Berlin Garden, Fr. Otto, with the legend: "wilde Kartoffel aus Rio Frio im Hochgebirge zwischen Puebla und Mexico, in einer Höhe von 10,000 Fuss über den Meerspiegel vorkommend."

[1] L. c., p. 329.

[2] L. c., p. 454.

The report of many travelers in Mexico and in the higher Andes of Peru and Bolivia is that in those regions where "wild potatoes" are found the night temperatures are very low and that light frosts may occur in almost any month of the year. It was to be expected that a species from such a region would show some frost tolerance.

The behavior of first-generation hybrids with *demissum* is interesting. Such hybrids have not been easy to secure and only a small number of plants were in the test, but, without exception, they withstood the two successive cold nights without injury. The hybrids and the number of seedling plants involved are: *demissum* x *maglia*, 7 plants; *demissum* x *fendlerii*, 13 plants, (a few terminal leaves showed very slight injury). Both *maglia* and *fendlerii* in the immediate vicinity were killed to the ground.

A wholly unexpected case of frost tolerance, however, appeared in a culture of *S. commersonii* Dunal and its hybrids. It adds another example to White's (10) list of warm-climate frost-tolerant plants. A very generous sample of seed was secured from the Director of the Botanical Garden in Montevideo under the name *commersonii*. The plants grown from this seed were all very uniform in appearance but differed in several minor particulars from *commersonii* secured from J. R. Baiz, Las Delicias, Argentina, or *commersonii blanca* from the same source, or from *commersonii* forma *silvestre* secured from J. B. Marchionato, La Plata, Argentina. This species presumably is limited to the coastal-plain region and, while it may be inferred that its ancestral home was in the hot equatorial region and that its present geographical distribution indicates a line of development significant of greater tolerance for cold, there seemingly is nothing in its present distribution to indicate a tolerance for below-freezing temperatures. This particular lot of *commersonii*, however, showed no injury whatever from the two freezes, although the three other families carried under this name were killed completely. Likewise first-generation hybrids with the *commersonii* from Montevideo exhibited a similar tolerance, whereas, such hybrids with *commersonii* from other sources were killed completely. Here again the number of plants involved is very small because of difficulty in effecting crosses. The hybrids obtained and the number of seedling plants on which the observations are based are as follows: *commersonii* (Montevideo) x *commersonii* (Las Delicias) 2 plants; *commersonii* (Montevideo) x *demissum* 12 plants. In the latter case the frost tolerance might be ascribed equally as well to the pollen parent. No records exist for hybrids in which the pollen was taken from *demissum* although, as will be mentioned below, Klotzsch found tolerance with the reciprocal. In the case recorded here, the plants involved are unquestionably hybrid because they resemble the pollen parent much more than they do the mother.

Some other plants in the experimental garden exhibited frost resistance. These were found among some varieties secured from Professor Knappe, in Estonia. 1. *S. commersonii* (Montevideo), doubtless from the same source as the plants mentioned above. 2. Caliban (*demissum* x Majestic). 3. Silhonetto (Sylvan x Hindenburg). 4. Also in some varieties secured from Dr. R. Schick, Müncheberg, Germany, to test for resistance to late blight (*Phytophthora infestans*), Wohltmann, Parnassia and Deodara proved to be not only very resistant to blight but also resistant to frost. Many other varieties were grown in the same field and those that had survived the blight were completely killed by the low temperature of September 20. Some of the varieties involved were Green Mountain, Russet Rural, Evergreen, Ekishirazu, and a long list of hybrids several of which were from Professor Knappe.

It is worthy of more than passing note that three German varieties out of a total of five included in the test should exhibit resistance to Phytophthora blight and tolerance for cold. Doctor Klotzsch (5) hoped that his *utile* would prove useful in combating "the potato disease." The hope of accomplishing this seems to have been great, for, a few weeks later, in the same publication (p. 356), the statement is found that Juhlke (3), gardener at Akademie Eldena, was growing nearly a half acre of seedlings of this species. This article usually is cited as authority for the susceptibility of this species to *P. infestans* and the article is commonly ascribed to Münter. Juhlke is responsible for the communication to the editor and Münter is quoted by him as saying that this ought to bring to an end the discussion about the potato disease being a degeneration caused by continued asexual propagation.

Whatever effect this announcement may have had on Klotzsch, it did not deter him from continuing work with the species. In 1851 he (5) says nothing whatever about the potato disease, but he reports that *utile* was not injured by frost of 2° (Réaum.) under the freezing point. He reports further that in the hope of introducing this frost tolerance into the ordinary varieties he had placed the pollen of "*tuberosum*" on *utile*, had secured a blend of the two and had grown the seedlings. At the end of March, half the seedlings were grown in pots out of doors where they were subjected several times to frost of 1½° (Réaum.) without injury.

BLIGHT RESISTANCE

The susceptibility of *S. demissum* to blight is recorded by Lindley in his original paper (6). With the great prevalence of blight at the time and the intense interest in the disease it would seem that no mistake could have been made either by Klotzsch or Lindley. It must be remembered,

however, that at that time *P. infestans* was not commonly regarded as the cause of blight but merely an invader of dead tissue. Its presence was not a diagnostic character. *S. demissum*, as grown at Ithaca, often shows a marginal burning of the leaves and occasionally this has become so severe that certain plants died completely. The cause of this burning is not known. It has much the appearance of blight as it occurs on the variety Rural New Yorker but *P. infestans* is not present. In fact, repeated attempts to infect this species artificially with *P. infestans* under thoroughly favorable conditions both with very small seedlings and mature plants have consistently failed. No lesion whatever is formed. Salaman (9) has grown the species, under the name *utile*, for 15 years and it has always been free from blight. It seems probable that Lindley and Juhlke were mistaken about the susceptibility of the species.

An attempt to relate the varieties Deodara, Parnassia and Wohltmann to Klotzsch's *utile* seems reasonable on the basis of two outstanding physiological characters. The immediate parents of these varieties are known. The first two are sibs of Deutsches Reich by Jubel. The latter is the offspring of Daber by Erste von Frömsdorf. An examination of all of the known treatises on systematics of the potato fails to reveal the lineage through many generations. None of the varieties mentioned in the lineage, so far as it can be traced, can be very old, for none is found in the long list of varieties (2) exhibited at Altenburg in 1875. Incidentally it is interesting and perhaps significant that in this list, mostly of varieties with German names, the exotic name "Rio Frio" should be attached to one of the old and well-tried (altbewährten Sorten) varieties and that among the novelties a variety was exhibited under the name "Dr. Klotzsch Bastardzucker."

All of the first generation hybrids of *demissum* mentioned above likewise exhibited complete immunity from *Phytophthora infestans*, both in greenhouse inoculation and in the field. Natural infection was very general in the experimental plot on susceptible sorts. An initial artificial inoculation had been made on a susceptible variety planted for the purpose. Subsequent weather conditions favored a natural spread of the disease. All of the plants of *demissum* and its hybrids had been grown from seeds. The seeds were planted in mid-April and the seedlings were transplanted to the field early in June. Seeds and tubers had formed at digging time (October 10) and the plants may be said to have matured even though they remained green. The inoculations made in the greenhouse were done in March, 1930, and a more extensive report will be presented later. The contention of K. O. Müller (7) that plants become susceptible to Phytophthora when they approach maturity is not supported by these observa-

tions, but, obviously, much more extensive tests must be made either to confirm or to deny his claim.

SUMMARY

Solanum demissum and *S. commersonii* from Montevideo were subjected on two successive nights to 29° F. without any apparent injury. Some first-generation hybrids of each of these species showed a similar frost tolerance. *S. commersonii* from three other sources, along with numerous varieties of *S. "tuberosum,"* were killed completely by the cold.

Solanum demissum is immune from *Phytophthora infestans* as are also some first-generation hybrids.

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GERMINATION OF THE OOSPORES OF SCLEROSPORA GRAMINICOLA (SACC.) SCHROET.[1]

M. M. Evans and George Harrar[2]

Comparatively little is known about the germination and function of the oospores of the Peronosporales. Most of our knowledge of the germination of oospores and their function goes back to de Bary's work. He has described the germination of the oospores of *Peronospora valerianellae* Fckl. (3), *Cystopus candidus* Lev. (1), and *Pythium debaryanum* Hesse (2). Moreover, he reports that the resting spores of *Peronospora valerianellae* and *Pythium debaryanum* germinate by a tube, while in *Cystopus candidus* the resting spores germinate by zoospores. Prillieux (11) has described and illustrated the germination of the oospores of *Plasmopara viticola* (B. and C.) Berl. and De T. He found evidence that the oospores produce a conidiophore. Gregory (6), as a result of more recent investigations, describes and illustrates the germination of the oospores of *Plasmopara viticola* by the formation of a tube or stalk bearing a conidium. This has been confirmed by Ravaz and Verge (12).

Gaümann and Dodge (5, p. 84) have this to say about the germination of the oospores of the Peronosporales: "The germination of the oospores in Plasmopara takes place through zoospores, in *Pl. viticola* under certain conditions also with a germ tube ending in a large conidium (Ravaz and Verge, 1913), in Sclerospora and Peronospora through a germ tube which develops in the host to a mycelium." Apparently, Gaümann and Dodge (5) overlooked Gregory's (6) report made in 1912 of the germination of *Plasmopara viticola*. Gaümann (4, pp. 81, 82) credits his statement on oospore germination of Sclerospora to de Bary, but we have been unable to find where de Bary referred to the germination of Sclerospora. Hiura[3] (7), in a very recent paper (1929), reports in a preliminary way the germination of the oospores of *Sclerospora graminicola* (Sacc.) Schroet. without referring to Gaümann's (4) statement on oospore germination of Sclerospora. Hiura (8) took the oospores from green leaves and placed them in soil water. Under favorable conditions the oospores germinated within 40 to 48 hours and developed hyaline, nonseptate, branched tubes that were three to 11 μ

[1] Published with the approval of the Director of the Iowa Agricultural Experiment Station.

[2] The writers are indebted to Professor I. E. Melhus for suggesting the problem and lending assistance in carrying out the experiments and preparing the manuscript.

[3] Attention is called to a yet more recent publication by Professor Hiura which describes fully a very unique method of germinating the oospores. This appeared during the time the present paper was in press.

Hiura, Makoto. A simple method for the germination of oospores of *Sclerospora graminicola*. Science 72: 95. 1930.

in width. The optimum temperature for germination is reported as between 27° and 30° C. Hiura (7) also refers to a visit to Mr. Da Nami, who showed him germinating Sclerospora oospores and related his method of inducing them to grow. Although the results had not been published, Mr. Hiura's description of Mr. Da Nami's results with germinating oospores leaves no doubt that the oospores were germinating, even though drawings or photographs of the process did not accompany his articles.

When the present work was started in the fall of 1928, the writers were not aware that any one had ever germinated the oospores of Sclerospora. The task of germinating the oospores of *Sclerospora graminicola* seemed hopeful because it was readily possible to bring about infection of *Setaria viridis* (L.) Beauv. seedlings in the soil with the oospores of *Sclerospora graminicola* by the method described by Melhus and Van Haltern (9) and Melhus, Van Haltern, and Bliss (10). This work showed that the oospores germinated and brought about infection of the host within a period of two days. After repeated trials germination of the oospores of *Sclerospora graminicola* was brought about by selecting clean infected tissue in the field in December, 1928, near Ames, Iowa. This was easily obtained by taking the reddish brown shredded tissue from standing Sclerospora-infected *Setaria viridis* plants. The reddish brown color is caused by the abundance of spores formed in the tissues killed by the organism. The oospore material from dry standing plants, as shown in figure 1, usually showed less con-

FIG. 1. A part of a *Setaria viridis* plant killed by *Sclerospora graminicola*. The shredded tissue consists of the fibrovascular bundles left after the pathogene has destroyed the parenchymatous tissues. Among the vascular tissues are abundant reddish brown oospores.

tamination than that collected after the plants had lodged. The oospores were shaken from the diseased tissue into a beaker of sterile distilled water. The spores floated on the surface; however, a few sank to the bottom of the container. From 5 to 30 per cent of the oospores were found to germinate in 24 hours when held at room temperature.

Where clean diseased tissue was not available, the oospores were surface-disinfected with a 5 per cent solution of lactic acid, washed in sterile distilled water, and then floated on sterile water in watch glasses and held at

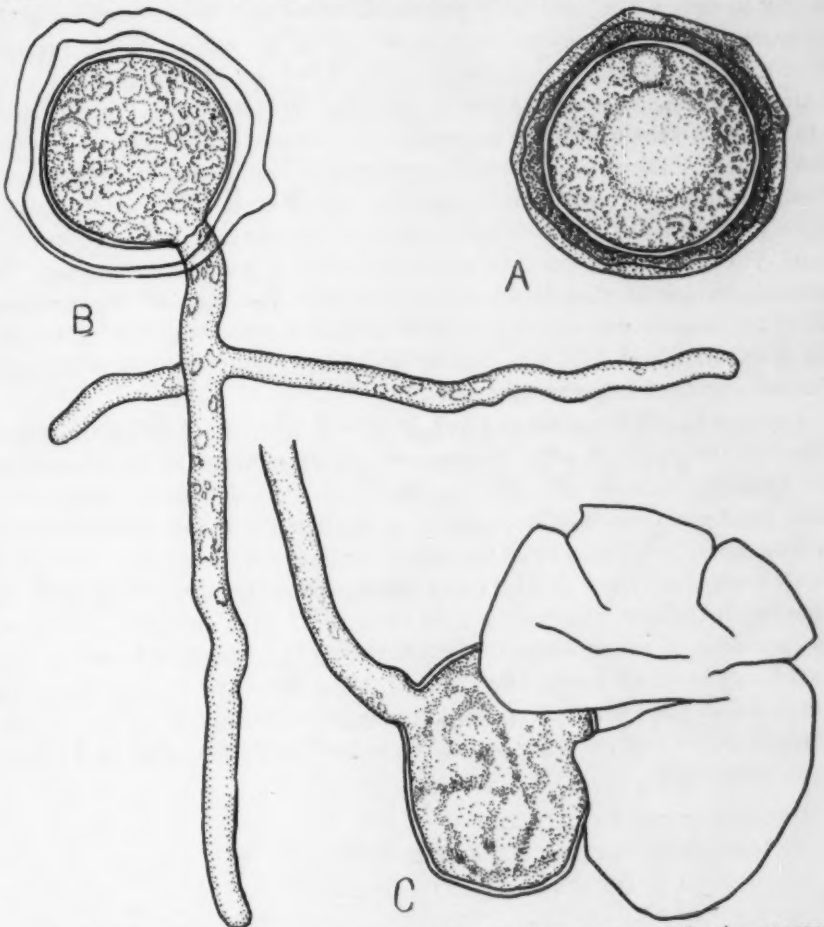

FIG. 2. Oospores of *Sclerospora graminicola*. A. Mature oospore showing exospore, endospore, and the endospore content. B. An oospore sending out a germ tube through a small opening in the exospore. There is direct continuity between the cell wall of the germ tube and the endospore wall. The cytoplasm in the germ tube is hyaline with relatively few granules present. C. The exospore in this oospore has been broken so as to show the exact relationship of the germ tube with the cell wall of the endospore.

18° C. for 24 hours. At the end of this period some of the spores had begun to push out germ tubes. These tubes were hyaline, branched, and contained some globular bodies, as shown in figure 2, A and C. Frequently, long stretches in the tubes seemed to be empty or nearly devoid of cytoplasm, as shown in figure 2, B. The large fat-globule always disappeared before the germ tube developed. Likewise, no evidence of the nucleus was seen in the germinating spores. The granular bodies mentioned were not nuclei. The walls of the tubes were a direct continuation of the endospore wall, as shown clearly in figure 2, C, and they protruded through a small opening in the exospore (Fig. 2, B), apparently dissolved by the action of the forming germ tube. At least, no pore was ever observed in a dormant oospore. The contents of the oospore were frequently seen to flow out of the endospore into the germ tube. In other instances, the contents in the germ tubes were seen to move. The rate of internal activity of the cytoplasm incident to germination under favorable conditions was pronounced. Repeated measurements of germ tubes, after 30 hours at room temperature, were 600 to 700 μ long. The diameter of the tube at the point where it comes out through the exospore wall is smaller in diameter than it is just outside the exospore. When the oospore was severely ruptured this condition was not noticeable. The diameter of the tube was usually about 5 μ. The length and diameter were greater than in many other fungi.

Changes in pH from 4.5 to 7 appeared to have little effect on the germination of the oospores. The oospores which germinated at room temperature branched extensively. The medium used seemed to make little difference; good germination was obtained on agar, malt, potato dextrose, corn-seedling agar, bouillon, and in soil agar. Neither aerial hyphae nor conidia were observed to form on the germ tubes. Occasionally, the ends of the branched tubes were enlarged, but in no case did such enlargement suggest the formation of a sporangium. Just how long these germ tubes would live in media or in water was not determined. The nature of the activity of the cytoplasm in the germinating oospore suggests that the germ tube might continue to live and grow for several days because of the large food reserve in the endosperm.

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DISEASES, NEW TO CITRUS, FOUND IN PALESTINE

I. REICHERT

During 1928 and 1929, a very important period in the development of the Citrus industry in Palestine, there appeared in this country some diseases entirely new to Citrus. Some of them appeared in a very grave form and caused much alarm among local growers. As these diseases are new to science they deserve to be made known to Citrus pathologists in other countries.

LITTLE LEAF

The growth of young orange and grapefruit trees, budded in the fall of 1927, was checked. The branches became stunted, the joints shortened, the leaves smaller, sometimes mottled, and frequently burnt at their tips (Fig. 1, A). The new branches did not bend downwards, as normally, but re-

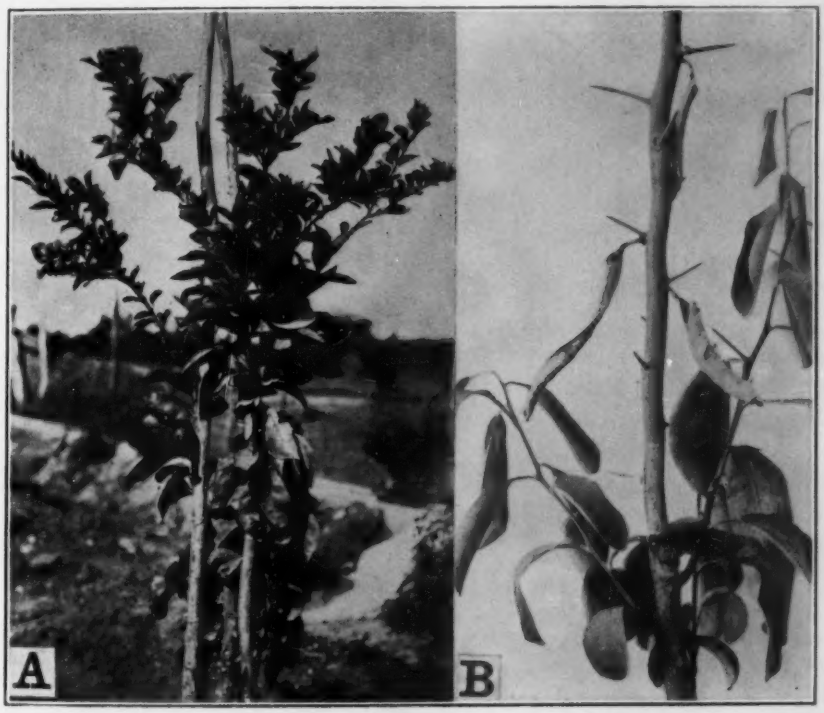

FIG. 1. A. Young orange tree affected with little leaf. (Photograph by J. Perlberger.)
B. Nonbudded sour-orange tree girdled by the spot disease.
(Photograph by F. Littauer.)

mained upright and formed a bush-like growth resembling, to a certain extent, the type of yellows and little-leaf diseases known in other fruit trees (11).

Many suggestions as to the possible cause of the disease, such as over-manuring, overwatering, etc., have been advanced by the growers, but none has been acceptable.

Cultural and histological examination of the diseased parts of the tree have not revealed any positive agent (7). The disease seems to be of a physiological nature, connected with the evaporation of the soil moisture and with the heavy loss of water from the young trees after being cut back. The low rainfall and long hot spells of 1928 caused an unusual desiccation of the young trees. The possible loss of calcium accumulated in terminal parts of trees during the hot spells by the usual cutting back of the stock as well as the pinching back of the young trees may also not be excluded (4).

STEM SPOTS

In the month of May, 1928, there appeared on the western side of non-budded one-year-old seedlings, especially sweet lemon, 10–20 cm. high from the collar, yellow sunken spots which spread and finally girdled the entire stem. As long as the spot was confined to one side of the seedling the branches of the affected side began to yellow and wither. Later on, when the whole stem had been involved, the entire crown withered and died (Fig. 1, B). The affected wood behind the spot had a dark grey appearance. The cortex bore on its surface dots of Alternaria fascicles. The wood vessels behind the spots were found invaded by a mycelium, a pure culture of which has not yet been obtained (8, 10).

Similar spots were found on young trees budded in the previous fall, but no case was known of a spot girdling a budded tree. The necrotic discoloration of the tissue did not go farther than half way up the stem. The wood tissue behind these spots also was found invaded by a mycelium. The damage caused by the second type of spot was particularly great. The disease seems to be of parasitic nature, but some contributing influence of climatic conditions, such as sun, winds, marine humidity prevailing on the western side, etc., must also be taken into consideration.

DYING BACK OF STOCK STUBS

A month after the upper part of the stock of budded trees had been cut back (in April, 1929), the remaining stubs began to die back. The affected part turned brown and the disease spread downwards to the collar. When it reached the bud, the crown began to wither and die back. Sometimes it happened that only the side of the stub opposite the scion had been affected and then the malady spread down to the collar without impairing severely

the growth of the tree. The wood tissue of the necrotic parts showed abundance of mycelium in the vessels. The fungus has not yet been isolated. This disease was found in one case to attack 12 per cent of the trees of a young orchard (8).

SPOTS BELOW THE SCION

This disease appeared especially in 1930. Its characteristic features are: the appearance of brown necrotic spots in the inner bark and wood close under the scion of two-year-old trees. A stunted growth is always associated with the appearance of these spots. The brownish wood tissue is filled up with abundance of fungus hyphae, similarly to the former case.

It is believed that this disease is a later stage of the former one—the dying back of stock stubs. In all these cases the stubs had certainly been affected but unnoticed by the grower who cut them back later. Then the malady spread downwards and caused the brown spots.

STEM ROT

The characteristic symptoms of this disease are the cracking and peeling up of the stem cortex and a discoloration of the wood below it. The under side of the cortex and the upper side of the stem wood are closely covered with numerous sclerotia of *Rhizoctonia bataticola* (Taub.) Butler (9). The rot can be traced down to the roots, where the trouble seems to start.

The association of *Rhizoctonia bataticola* with Citrus stem and root rot hitherto has been reported only from Ceylon (12) where the disease has been found on orange and lime, from the West Indies (2) only on lime, and from Rhodesia (6) only on the orange. Since Ashby (1) and Haigh (5) have shown the existence of 3 strains—A, B, C—in *R. bataticola* characterized by the difference in size of the sclerotia (strain A produces sclerotia of about 1 mm., B of about 200 μ, and C of about 100 μ), it is doubtful whether the strains of *R. bataticola* associated with the Citrus root rots in the above countries are identical. The Palestine strain is in any case not identical with that of Rhodesia. The sclerotia described by Hopkins (6) are of the A-strain type, whereas our fungus belongs to the C strain. Whether the Ceylon and West Indies sclerotia belong also to the C strain has yet to be determined.

Whether *Rhizoctonia bataticola* is the primary cause of collar and root rot of trees, as believed by Small (13), or is of secondary nature, according to Gadd (3), can not yet be said with certainty.

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PHYTOPATHOLOGICAL NOTES

CITRUS DISEASES NEW TO PALESTINE.—In the course of a recent trip through the citrus-growing sections of Palestine the writers encountered the following diseases not previously recorded in Palestine. These were found only in a few places and are not of general distribution.

Exanthema: This disease was found on orange in sandy soil in an orchard not far from the sea. The "stag-horn" appearance of the branches, shortened nodes, multiple buds, curved branches, and stained terminals were evidence of the disease, but the gum pockets usually found on the twigs in connection with the disease elsewhere were absent. This disease is not to be confused with little leaf,[1] which has an entirely different appearance.

Sclerotinia twig blight: This twig blight, caused by *Sclerotinia sclerotiorum* (Lib.) Massee (*Sclerotinia libertiana* Fuckel), was found on a few twigs of lemon trees, *Citrus lemonia*. The dead whitened twigs with formation of sclerotia on the surface indicated the disease. It was not found generally and, up to the present, is of no economic importance in Palestine. The same fungus, however, was doing much damage to bananas in the Jaffa district in 1929–1930, as was found by the Division of Plant Pathology of the P. Z. E. Agr. Exp. St., Tel-Aviv. Oranges inoculated in the laboratory at that time contracted sclerotinia rot. On this basis it was predicted that the disease would soon be found on Citrus in Palestine.

Mal secco: This disease on the twigs, as described by Petri and as distinguished from blast and anthracnose, was found in two orchards on lemon, sour orange, citron (Ethrog), and possibly sweet lemon. The dying back of twigs and the pink discoloration of the wood occurring at considerable distances from the discolored bark and dead end of twigs was like that seen in Sicily. The small-spore Phoma-like fungus was isolated.

Psorosis: This disease, though mentioned once before,[2] is not yet to be considered a serious disease in Palestine. It was identified certainly only in one orchard on Valencia trees. What appeared to be psorosis was also seen in a few old orange groves. Its presence on these trees, however, was somewhat doubtful.—I. REICHERT and H. S. FAWCETT, *Tel-Aviv, Palestine, and Citrus Experiment Station, Riverside, Calif.*

[1] Reichert, I. Palestine Citrograph, **1**, No. 11/12, 16–17. 1928.

[2] Ryerson, K. A. The horticultural possibilities of Palestine. Rep. of experts submitted to Joint Palestine Surv. Comm., p. 287. 1928.

Die-back of elm in Minnesota.[1]—During the past two years there has been considerable dying back of elms in Minnesota. The damage seems to be chiefly in nursery stock 10 to 15 feet high, although the disease also occurs in small stock and in larger shade trees. During the summer of 1929 the disease was prevalent throughout the nurseries of the State, suggesting that it may have been present for several years. The number of infected shade trees is yet small, but in some nurseries as high as 25 to 50 per cent of the larger stock is infected.

The causal organism appears to enter through the tips of the branches and works downward through the wood and bark until it reaches the roots. In one shade tree (15 feet high) in St. Paul the fungus had reached the roots and killed the entire tree the second season after the first wilting was observed. The path of the organism through the wood is marked by brownish streaks that may be in a definite ring, as those described for *Graphium ulmi* Schw. in Europe, or, as is more often the case, diffused throughout the wood. The organism finally extends into the cambium and phloem, killing these tissues, but this may not occur until after the leaves have wilted. In many cases the organism appears to invade the cambium and phloem first, causing reddish, sunken cankers.

Isolations made from diseased trees in St. Paul, Minneapolis, Albert Lea, Owatonna, Virginia, Hamel, and Lake City, Minnesota, showed that one fungus was constantly associated with the disease, although other organisms were sometimes present, especially in dead and dried areas. As no fructification of the fungus has been found on elm, positive identification has not been made. In culture, groups of abortive pycnidia containing minute, hyaline, elongate spores are borne in stromata. This places the organism among the Sphaeropsidales, possibly near *Cytosporella.*

About 50 healthy, vigorously growing elms, 2 to 5 feet high, were inoculated during August, 1929, by placing mycelium in agar on freshly exposed wood and covering the inoculum with grafting wax or adhesive tape. When the leaves dropped in the fall no infection had occurred in many of the trees, and in those that became infected the fungus had advanced only 1 to 2 cm. from the point of inoculation. Later, larger trees (1 inch in diameter) were transplanted to the greenhouse and inoculated in a similar manner. Three months after inoculation the trees were dead, the stems being girdled at the point of inoculation and the discoloration extending 5 to 30 cm. from the wound. Transplanting and environmental conditions had noticeably reduced the vigor of these trees. Reisolations showed that the original fungus was present in the diseased areas. Additional inoculations will

[1] Published with the approval of the Director as Paper No. 943 of the Journal Series of the Minnesota Agricultural Experiment Station.

have to be made on vigorous trees in the field in order to determine whether the fungus can kill vigorously growing trees.

Many of the diseased elms in nurseries were in very poor condition, some quite evidently suffering from severe hail and insect injury; others, perhaps from too close cultivation and undercutting, which had reduced the root system severely. In other cases (except for the disease in question), the trees appeared healthy. Observations and inoculations so far made have not shown satisfactorily how virulent the pathogene is and to what extent it will develop in healthy trees. That it is constantly associated with the disease and can kill weakened trees seems, however, to be definitely established. Further investigations are under way.—A. F. VERRALL, *University Farm, St. Paul, Minn.*

THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

CONSTITUTION[1]

ARTICLE I

This Society shall be known as The American Phytopathological Society.

ARTICLE II

MEMBERSHIP

Sec. 1. The Society shall consist of members, and may include life members and patrons.

Sec. 2. The charter membership of this Society shall consist of the one hundred and thirty persons who accepted the invitation of the Organization Committee of October 25, 1909, to form the Society.

ARTICLE III

QUALIFICATIONS FOR MEMBERSHIP AND DUES

Sec. 1. All persons interested in the study of phytopathology, including the practical control of plant diseases, shall be eligible to membership.

Sec. 2. Each member shall pay annually such dues as the Society shall determine.

Sec. 3. Any member may become a life member by paying one hundred dollars in ten consecutive annual payments, and any person may become a patron upon the payment of one hundred dollars, and upon election shall have all the privileges of membership.

ARTICLE IV

ELECTION OF MEMBERS

Members may be elected at any regular meeting of the Society or by the Council during the interim. Applications for membership must be endorsed by at least one member of the Society.

ARTICLE V

OFFICERS

The officers of the Society shall consist of a President, Vice President, and Secretary-Treasurer. Their duties shall be those usually performed by such officers. The President and Vice President shall serve for one year and the Secretary-Treasurer for three years, or until their successors are elected, and the Council shall fill any vacancies occurring in the interim between elections.

The Council shall consist of the President, Vice President, Secretary-Treasurer, the retiring President, and the Chairman of the Board of Editors of the Journal of the Society, with two members elected, one each year, who shall serve for a term of two years, and one member elected annually by each Division. The term of service of a Council member from a Division shall commence at the end of the annual meeting of the Society next following his election by the Division.

All action of the Council or officers must be authorized or approved by the Society.

[1] At the 1928 meeting, the incoming and outgoing officers of the Society were directed to prepare a revision of its constitution. This was done, and the proposed changes which were submitted to members one month in advance of the 1929 meeting were later approved by the Society in session at Des Moines. The last printing of the constitution was in PHYTOPATHOLOGY, Vol. 15, No. 10, October, 1925.

ARTICLE VI

ELECTION OF OFFICERS

The Secretary-Treasurer shall send nomination ballots for offices to each member of the Society in time to allow all nominations to be returned not less than two months before the date of the annual meeting. The Council shall make nominations for any office when such nominations are wanting. The three candidates for each office receiving the highest number of nominating votes shall be placed upon a final ballot, which shall be sent to each member one month before the annual meeting. Votes shall be mailed to the Secretary-Treasurer and canvassed by the Council. A plurality vote shall elect.

ARTICLE VII

EDITORS, COMMITTEES, AND APPOINTMENTS

The Editors of the official organ of the Society shall be selected by the Council subject to the approval of the Society.

Temporary or standing committees may be appointed at the discretion of the Society.

Unless otherwise directed, the President shall appoint all temporary committees that are to serve during his administration and shall fill all vacancies on standing committees that may occur during his term of office.

ARTICLE VIII

MEETING

An annual meeting shall be held at such a time and place each year as the Council may select, and additional meetings, including special or local meetings, for the presentation of papers, may be arranged by the Council at its discretion.

ARTICLE IX

DIVISIONS

Branch organizations or units within the Society, known as Divisions, may be established on a geographical basis, provided formal application setting forth the reasons for the establishment of the Division is made to, and approved by, the parent Society.

ARTICLE X

AMENDMENTS

This Constitution may be amended at any annual meeting by a three-fourths majority of all the members voting, notice of the proposed amendment having been sent to all the members at least one month previous to the meeting.

STANDING RULES

The rules under which The American Phytopathological Society operates are as follows:

PHYTOPATHOLOGY

1. The official publication of the Society shall be PHYTOPATHOLOGY.

   a. *Officers.* The officers of PHYTOPATHOLOGY shall be an Editor in Chief, term three years; three Editors, terms three years; twelve Associate Editors, terms three years, four selected each year; Business Manager, term one year; and Advertising Manager, term one year.

   b. *Selection of Officers.* The Editor in Chief and the Business Manager shall be selected by the Council and approved by the Society. The Editors and

the twelve Associate Editors shall be selected by the Council in consultation with the Editor in Chief and approved by the Society. The Advertising Manager shall be selected by the Council in consultation with the Business Manager and approved by the Society.

c. *Subscriptions, Back Numbers.* Subscriptions to PHYTOPATHOLOGY for institutions and nonmembers shall be $6 per year in the United States and dependencies, Mexico, and Cuba; Canada $6.25; other countries $6.50. The price of current single numbers shall be 60 cents. The price of back volumes and numbers shall be determined by the business manager with the approval of the Council. Separate copies will not be sold except in cases where the volumes are already broken. Requests to supply lost copies of the journal without charge must be made within sixty days from date of issue.

DUES

2. The annual dues for each regular member, including subscription to PHYTOPATHOLOGY, shall be $5 per year, payable on December 20. The Business Manager of PHYTOPATHOLOGY shall discontinue sending the journal to any members whose dues have not been received by December 20.

PAPERS, ABSTRACTS

3. Members desiring to present papers at the annual meeting must furnish to the Secretary-Treasurer carefully prepared abstracts presenting as clearly and concisely as possible the substance and conclusions of the papers, these abstracts to embody definite results and not to exceed two hundred words in length.

a. *Date Due.* The Secretary-Treasurer is authorized to refuse abstracts received by him after the date on which they are due (Nov. 15). Members are requested not to submit titles or abstracts unless they intend to be present at the meetings.

b. *Number of.* No member shall be permitted to present more than two papers at any one meeting, except by invitation, and, in case of joint authorship, the paper shall be charged to the author presenting it.

c. *Editing of.* All abstracts shall be submitted to an editorial committee of at least three selected by the Editor in Chief of PHYTOPATHOLOGY, and this committee will edit the abstracts in the same manner as original articles published in PHYTOPATHOLOGY.

PROGRAMS

4. The program for the annual meeting shall be in charge of a program committee consisting of the President, Vice President, and Secretary-Treasurer. To relieve congestion the program committee is authorized to schedule simultaneous sessions when necessary.

DIVISIONS

5. The following provisions shall govern the organization and regulation of Divisions of the Society.

a. *Name of.* Divisions shall use the name of the parent Society with the appropriate geographical term, for example, The American Phytopathological Society, Pacific Division.

b. *Membership.* Divisions shall elect to full membership only members of The American Phytopathological Society, but each Division may elect associate members under such rules as it may adopt.

c. *Publication.* The proceedings of Divisions shall be printed in PHYTOPATHOLOGY. The preliminary abstracts of the Division meetings may, at the discretion of these Divisions, be printed in PHYTOPATHOLOGY under the same rules that govern publication of abstracts of the general Society. This rule, however, shall not be interpreted as limiting the present right of the Editorial Board of PHYTOPATHOLOGY to define the character and amount of any manucript for publication.

d. *Meetings of.* Whenever The American Phytopathological Society meets within the territory of a Division, the Division shall merge its program with that of the parent Society. The scientific sessions of such a meeting shall be presided over alternately by the President of The American Phytopathological Society and the President of the Division. Business sessions may be independent.

e. *Constitution of.* The constitution or articles of organization of all Divisions shall contain a provision or provisions ratifying the above rules. The constitution of all Divisions shall contain nothing in conflict with the constitution of The American Phytopathological Society. With the exceptions defined by the above rules, the Divisions shall enjoy complete autonomy.

SECRETARY'S EXPENSES

6. Unless otherwise ordered, the Secretary-Treasurer and the President, or, in case of his inability to attend, the Vice President, are authorized to attend the annual meetings of the Society at the Society's expense.

AUDITING COMMITTEE

7. At each annual meeting the President shall appoint an auditing committee to audit the accounts of the Secretary-Treasurer of the Society and the Business Manager of PHYTOPATHOLOGY.

UNION OF BIOLOGICAL SOCIETIES

8. The Society shall participate in the work of the Union of American Biological Societies and designates its Secretary-Treasurer and Editor in Chief of PHYTOPATHOLOGY as its representatives unless otherwise voted.

BIOLOGICAL ABSTRACTS

9. The Society shall provide for a standing committee of five with terms of five years, one member being chosen each year, to cooperate with the Board of Editors of *Biological Abstracts.*

CROP PROTECTION INSTITUTE

10. Representation on the Board of Governors of the Crop Protection Institute shall be provided for by three trustees, with three-year terms, one selected each year, these trustees to be chosen by the Council.

NATIONAL RESEARCH COUNCIL

11. Representation on the Division of Biology and Agriculture of the National Research Council is provided for in the following way. The various societies represented in the Division are classified into groups. This Society and the Society of American Bacteriologists constitute Group V. This group, as is the case with the others, likewise is entitled to one representative. Each Society shall designate an elector and an alternate for three-year terms. The two electors are to choose the representative on the Division for Group V, either one of themselves, or a member of one of the societies, the societies being taken in rotation. The term of the representative shall be three years. The elector from the society not having the representative on the Division in a given period, or some other member whom the Society may select, shall serve as an advisory representative without vote, and without expenses paid by the National Research Council, and may attend divisional meetings to present directly any business of his society.

The elector and alternate of The American Phytopathological Society, terms three years, shall be selected by the Council of the Society and approved by the Society.

OTHER REPRESENTATIVES

12. The following shall be selected by the Council and approved by the Society: two representatives on the Council of American Association for the Advancement of Science for one-year terms; one trustee on the Tropical Plant Research Foundation for a five-year term, and one member of the Editorial Board of the American Journal of Botany for a three-year term.

AMENDMENTS

13. These rules may be amended by a majority vote of the members voting at any regular meeting of the Society.

ANNUAL WINTER MEETING

The American Phytopathological Society will meet in Cleveland, Ohio, during the period Tuesday, December 30, 1930, to Thursday, January 1, 1931, sessions being held at Western Reserve University. Headquarters will be at the Hotel Hollenden. Joint meetings with other organizations are planned as follows: (1) with Section G on Tuesday afternoon, the papers being of general interest, and (2) with the Mycological Section of the Botanical Society of America on Wednesday morning in a de Bary Memorial program. Simultaneous sessions have been scheduled for presentation of a large number of interesting papers dealing with recent developments in research. On Tuesday afternoon provision has been made for a conference on extension work in plant pathology. The annual dinner will be held at 7:00 P. M., Tuesday, December 30, 1930, at a place to be announced later. As usual, details of arrangements will be mailed to all members.

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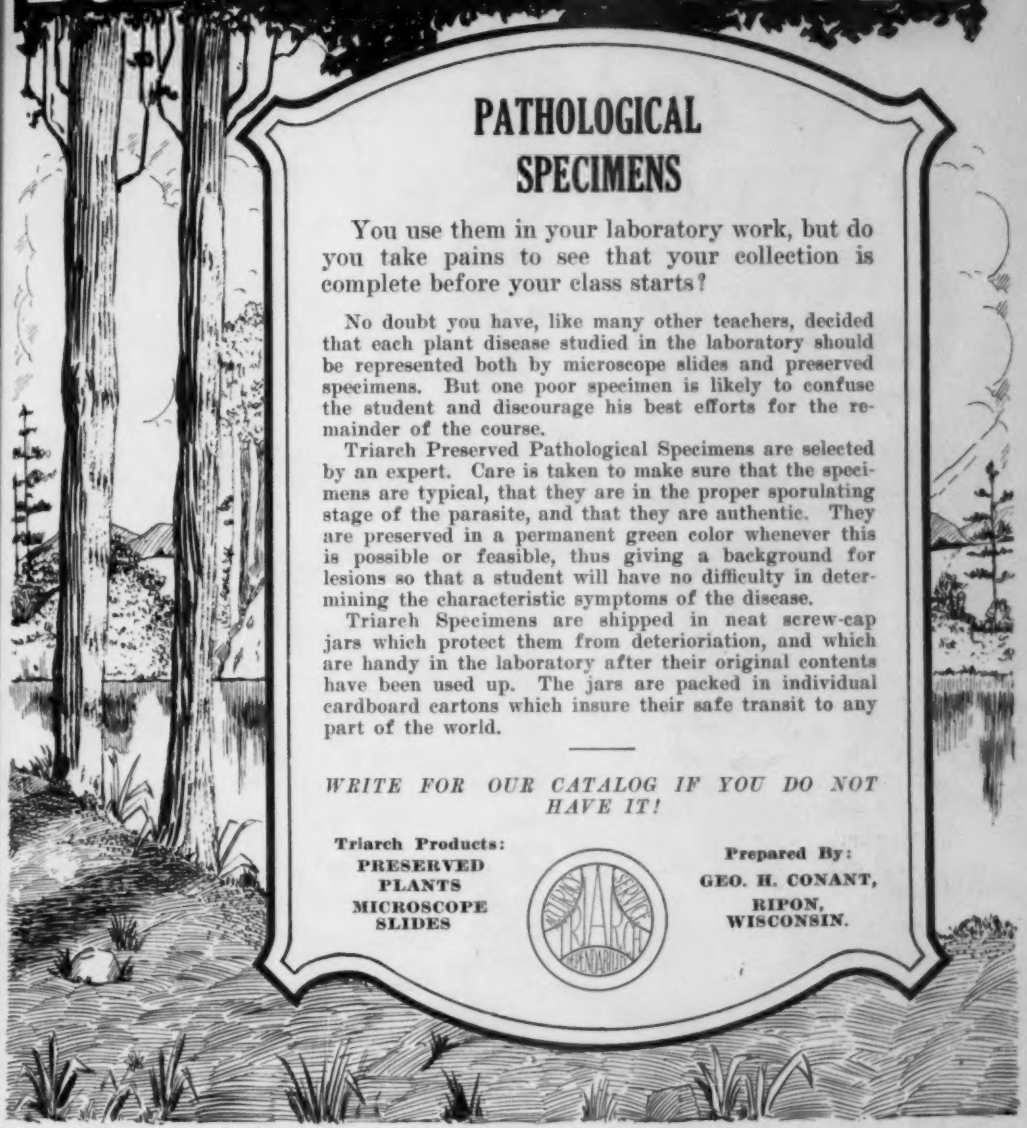

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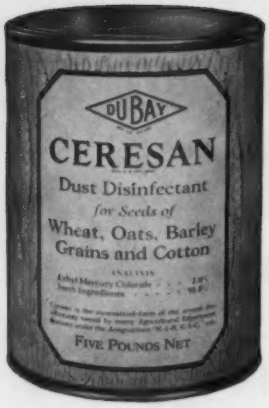

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